US Army Corps
of Engineers
Walla Walla District

Lower Granite Reservoir In-Water Disposal Test:

Results of the Fishery, Benthic and Habitat Monitoring Program-Year 4 (1991)

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Completion Report

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MONITORING FISH COMMUNITY ACTIVITY AT DISPOSAL AND REFERENCE SITES IN LOWER GRANITE RESERVOIR, IDAHO-WASHINGTON YEAR 4 (1991)

Completion Report

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EXECUTIVE SUMMARY

Completion of the Lower Granite Lock and Dam Project on the Snake River in 1975 provided electrical power production, flood control, navigation and recreation to the eastern Washington-west central Idaho areas. Sediment deposition from upstream sources is jeopardizing many of the legislated uses of this project, as approximately 800,000 cubic yards (611,680 m^3) of material deposit annually in the upstream portion of Lower Granite Reservoir. The large quantity of this material has necessitated dredging and consideration of in-water disposal downstream of river mile 120 (RM 120) as a management alternative.

Dredging began in 1986 with land disposal and experimental in-water disposal was initiated in 1988. Two in-water disposal sites were examined; in 1988 a mid-depth site originally 20-40 ft (6.1-12.1 m) deep was modified to a depth of 6-12 ft (1.8-3.6 m) thereby creating an underwater plateau, and in 1989 an island was created immediately downstream of the underwater plateau. Monitoring of the fish and benthic communities began in 1988. This report provides information on the results of monitoring changes in the fish community and utilization of these created habitats in year-4 (1991).

OBJECTIVES

1. To monitor abundance of larval, juvenile, and adult predators with special emphasis on northern squawfish *Ptychocheilus oregonensis* at in-water disposal sites and compare with those of reference sites;

2. To assess white sturgeon *Acipenser transmontanus* abundance and habitat factors associated with their abundance in Lower Granite Reservoir;

3. To estimate juvenile salmonid fish consumption by northern squawfish in Lower Granite Reservoir;

4. To assess age-0 chinook salmon *Oncorhynchus tshawytscha* abundance in Lower Granite Reservoir and assess the potential suitability of the disposal sites for rearing of age-0 chinook salmon; and

5. To compare benthic community structure and abundance at disposal and reference sites.

STUDY AREA

Ten sampling stations were used to monitor fish abundance during 1991 in Lower Granite Reservoir (Figure 1). Stations sampled to evaluate the use of dredged material to enhance habitat included stations 1, 2 and 4. Stations 3, 5, 9 and 10 were shallow water reference stations; one additional reference station (11) was sampled for larval predator abundance. Twenty two stations were sampled to assess age-0 chinook salmon abundance and habitat use (Figure 2) and nine additional stations between RM 108.0 and RM 137.1 were selected to assess white sturgeon abundance (Figure 3).

Objective 1. To monitor abundance of larval, juvenile, and adult predators with special emphasis on northern squawfish at in-water disposal sites and compare with those of reference sites.

We used several gear types during 1991 to make representative fish collections in Lower Granite Reservoir. Gear types included gill nets, beach seines, electrofishing, surface trawling, and half-meter plankton nets and a handbeam trawl. Gill nets were used to assess the relative abundance of potential predators and white sturgeon in pelagic waters. Surface trawling was used to sample pelagic salmonid abundance. Beach seining and electrofishing were used to sample shallow water stations during diurnal and nocturnal hours, respectively. Plankton nets and a beam trawl were used to assess predator distribution and estimate larval predator abundance.

Sampled larval fishes were preserved and later identified to species and measured. All fish larger than larval size were identified to species and measured to total length (mm). Most fish collected were released immediately after data collection, while channel catfish and northern squawfish were sacrificed for assessment of salmonid smolt predation (Objective 3). Adult salmonid fishes were released immediately without being removed from the water.

A total of 15,689 fish representing 24 species were collected at ten sampling stations in Lower Granite Reservoir during 1991. Higher numbers were collected during the spring (n = 8,751) and summer (n = 4,852) followed by fall (n = 2,086). Spring sampling accounted for 55.8% of the total number of fish collected. The spring sample was

represented by 23 species compared to 16 during the summer and 20 species in the fall.

Size of fish sampled in Lower Granite Reservoir during 1991 was related to gear type and season. Generally, larger fish were collected by gill nets whereas smaller fish, primarily age-0 and 1, were consistently collected by beach seine. Electrofishing collected a wide range of sizes especially in the spring and fall. Surface trawling collected exclusively juvenile chinook salmon and steelhead *Oncorhynchus mykiss*.

During spring, the majority of fish sampled in Lower Granite Reservoir were between 50-500 mm. Fish collected at shallow water stations were generally smaller than those collected in deeper waters. Shallow water reference and disposal stations had higher numbers of fish sampled between 50-100 mm during the summer accounting for > 50% of all fish sampled. Length frequencies of all fishes sampled during fall differed from both spring and summer in that fewer smaller fish were present.

Largescale suckers *Catostomus macrocheilus* dominated total catches at all stations and during all seasons accounting for 25.7% of all fish collected. The highest abundance of largescale suckers (n = 539) was at shallow water reference station 5 during spring. Juvenile chinook salmon were second in abundance during spring and the highest numbers were also collected at station 5 (n = 996). The majority of juvenile chinook salmon and juvenile steelhead collected were sampled by surface trawling. Smallmouth bass *Micropterus dolomieui* were third in abundance

during spring, second during summer and first during fall of all fish collected. Northern squawfish were collected in highest abundance at disposal station 1 during the summer (n = 253) and fall (n = 76). White sturgeon were collected only at reference station 8 and disposal station 2 during spring and fall. Other sturgeon collected were associated with Objective 2.

During 1991, comparisons of catch/effort of juvenile chinook salmon sampled by surface trawling in open water were not statistically different ($P > 0.05$) at reference stations 5 and 6 and the forebay, whereas differences in catch/effort were significantly lower at disposal stations 2 and 4. During 1989 and 1991, catches of juvenile chinook salmon by surface trawling were significantly higher at reference station 5 than at disposal station 2. No statistical differences in catch/effort were found for juvenile steelhead sampled by surface trawling during 1991. In addition, no differences in catch/effort were found among stations for juvenile chinook salmon and juvenile steelhead sampled by nighttime electrofishing.

Nighttime abundance of northern squawfish sampled by electrofishing during 1991 was variable among stations, but the highest catches occurred at reference station 5. Reference station 9 and disposal station 2 had significantly ($P < 0.05$) lower catch rates than reference stations 5 and 3. Daytime abundance along the shoreline of primarily smaller northern squawfish was highest at reference stations 5 and 10 and lowest at reference station 9. Differences in catch/effort by beach seining for northern squawfish at disposal stations 1 and 2

were intermediate to reference stations 10 and 9. Comparison of catch/effort of northern squawfish sampled by gill netting indicated that higher catches were found at reference stations 5 and 6. Catches by gill netting at disposal stations 2, 1 and 4 were significantly lower than those at stations 5 and 6. The majority of squawfish captured by gill netting were adult sized fish. No seasonal differences in catch/effort by gill netting were found in 1991.

The abundance of channel catfish *Ictalurus punctatus* based on gill net collections varied among stations during 1991. The abundance of channel catfish generally was highest at reference station 8 during spring and fall whereas comparisons of catch/effort at disposal stations were significantly ($P < 0.05$) lower.

Nighttime catches of smallmouth bass by electrofishing were higher at reference stations 9, 10 and 3 followed by disposal stations 1 and 2, however little statistical significance was found among stations. Daytime abundance of smallmouth bass along the shoreline based on beach seining was highest at reference station 10 followed by disposal station 1, whereas catches were lowest at reference station 5. Abundance of smallmouth bass sampled by all gear types was lowest at mid-depth disposal station 4 and reference station 6.

Few white sturgeon were collected at reference and disposal sampling stations in 1991. The abundance of white sturgeon was similar among stations, except at reference station 8 where abundance was significantly ($P < 0.05$) higher.

We continued to monitor the abundance of larval fishes during 1991. As in previous years, the highest catches were at shallow water reference stations 5 and 11. Density of larval northern squawfish was highest at shallow water reference station 11 and low at the disposal stations.

To date our sampling results indicate that few changes have occurred in the fish community since 1985. Centrarchid fishes have generally increased in abundance and redside shiners *Richardsonius balteatus* have decreased. Northern squawfish have remained about at the same level of abundance. Numbers of smallmouth bass have increased, possibly because of more stable water levels, warmer waters and lower seasonal flows in Lower Granite Reservoir. We have not found any change in the structure of the fish community that could be attributed to the in-water disposal at the island and mid-depth plateau.

Objective 2. To assess white sturgeon abundance and habitat factors associated with their abundance in Lower Granite Reservoir.

White sturgeon sampling was conducted in Lower Granite Reservoir from April through mid-November 1991. Gill netting was the primary technique used to assess white sturgeon abundance, although setline sampling was also conducted in 1991. All captured sturgeon were measured, weighed, marked and released.

A total of 545 white sturgeon generally between 12.1 and 265 cm were collected in Lower Granite Reservoir in 1991. Population abundance was estimated at 1,372 sturgeon > 45 cm. White sturgeon were not evenly

distributed in Lower Granite Reservoir, as highest catches were at RM 137.1 (R3S12, near stations 12 and 13) and 133.7 (R3S9, near station 14) and abundance progressively decreased downstream. Deep water (> 20 m; > 60 ft) in both lower and mid-reservoir sections were not considered significant habitats for white sturgeon based on number of fish collected. Habitat characteristics in the upper reservoir appear more suitable for white sturgeon than the lower reservoir. Velocities ranging from 0.031-0.61 m/s have been correlated with sturgeon abundance in other systems and our data corroborate these findings. Recaptured fish travelled an average of 11.2 river miles upstream and 5.2 river miles downstream and the majority of recaptures occurred in the upper reservoir. Seven of 105 recaptures migrated > 15 river miles.

We captured 14 sturgeon measuring < 20 cm total length during 1990 and 1991. These were probably age-0 fish which suggest reproduction is occurring. Access to free flowing, riverine habitat upstream from Lower Granite Reservoir provides a combination of spawning and rearing habitat which probably relates to the apparent high abundance in the upper reservoir.

Objective 3. To estimate juvenile salmonid fish consumption by northern squawfish in Lower Granite Reservoir.

Stomachs of northern squawfish (> 250 mm) collected from Lower Granite Reservoir during 1 April through 30 July, 1991 by all gear types between RM 112.5 (near station 6) and RM 132.0 (near station 16) were examined for food items.

A total of 218 northern squawfish were sampled for presence of smolts in their stomachs. Crayfish and fishes were dominant food items for northern squawfish sampled from Lower Granite Reservoir during spring 1991. Salmonids were present in many squawfish stomachs, although substantial differences (about 50% less) were found among squawfish consumption of smolts between 1990 and 1991. Daily ration of chinook salmon by squawfish during May 1990 was about 4.5 mg/g/d, whereas in 1991 it was about 1 mg/g/d.

During 1991, mean daily ration estimates of salmonids by squawfish increased from April to May and decreased in June. The majority of salmonids consumed in April were juvenile chinook, whereas those in May were mostly juvenile steelhead. Total daily ration of all non-salmonids for squawfish was highest in June at 2.725 mg/g/d. Mean consumption estimates were 0.38 prey/predator/d for chinook and 0.013 prey/predator/d for steelhead. Combined estimates of salmonid consumption for 1991 in Lower Granite Reservoir from RM 112.0 to RM 132.0 were 67,076 smolts.

Our estimates of salmonid smolt consumption differ from others for Lower Granite because of slight differences in data analysis. The unknown population size of northern squawfish in Lower Granite Reservoir seems to be the largest obstacle in precisely estimating salmonid smolt consumption by northern squawfish.

Objective 4. To assess age-0 chinook salmon abundance in Lower Granite Reservoir and assess the potential suitability of the disposal sites for rearing of age-0 chinook salmon.

Age-0 chinook were collected by beach seining and electrofishing during 1991 using identical methods employed for juvenile predator sampling (Objective 1). Areas of concentration of age-0 chinook were identified and measurements of macrohabitat characteristics were taken.

A total of 299 age-0 chinook salmon were captured by beach seining between 4 April through 28 June, 1991. No age-0 chinook salmon were collected after 28 June, 1991. The highest catch/effort by beach seining in 1991 occurred on 27 May about 1 week earlier than in 1990.

Ninety-five percent of all age-0 chinook were captured over substrata that consisted of > 75% fines (< 2 mm in diameter), whereas the remaining 5% of age-0 chinook were captured over substrata that consisted of > 75% fines and sand/cobbles (< 50 mm in diameter). During 1991, 2% of the age-0 chinook collected were captured at the disposal area (stations 1 and 2). This proportion is considerably lower than the 11% age-0 chinook captured at the in-water disposal stations in 1990. Disposal of dredged material seems to be an effective technique to create suitable rearing habitat for age-0 chinook salmon.

Objective 5. To compare benthic community structure and abundance at disposal and reference sites.

We used a Shipek dredge (1,072 cm^2) to sample at disposal stations 1, 2 and 4 and reference stations 3, 5, 6 and 8 during September 1991. Four dredge samples were taken along three evenly spaced transects at each station providing a sample size of 12 per station. Collected organisms were identified to the lowest taxon possible and enumerated and wet weights were measured.

As in previous years, the majority of organisms found in the benthic samples were oligochaetes (45%) and chironomids (55%) by weight. The highest standing crop of benthos was at reference station 6 (9.86 g/m^2) followed by reference station 5 (7.92 g/m^2) and mid-depth disposal station 4 (7.36 g/m^2). Mean chironomid standing crop generally decreased from 1988 and 1989 estimates. Largest decreases in numerical density of chironomids occurred at reference station 5 where numbers decreased from 1,949/m^2 in 1988 to 390/m^2 in 1991. Oligochaete standing crop also decreased in 1991 from previous sampling years. The largest decreases in standing crop estimates of oligochaetes were at reference stations 6 and 8.

Although chironomid biomass generally decreased from 1988, 1989 and 1991, it increased at mid-depth disposal station 4. We attribute this increase to a gradual increase in organic matter. These findings suggest the benthic community required about 4 years to become statistically similar to the reference stations. Sampling in 1992 will determine if further increases in the benthic community are occurring at

disposal station 4. We have not found any real changes in the benthic community at the island disposal stations (1 and 2) where the community has remained low in abundance since 1989.

DISCUSSION

Based on our sampling, disposal of dredged materials in Lower Granite Reservoir has not altered the fish community. Fish community characteristics such as species composition, size structure and relative abundance are generally similar to results from a survey conducted in 1985. Numbers of fishes, catch/effort of species of interest, and overall abundance of younger life stages have changed little. Based on our collections, age-0 chinook salmon use the shorelines at Centennial Island for rearing, although their relative abundance in 1991 decreased from that in 1990. Habitation of age-0 chinook around the island may be related to density dependent factors upstream as those must be saturated prior to overflowing downstream to the island or other downstream parts of Lower Granite Reservoir. In general, age-0 chinook salmon appear to rear at stations that typically have fines for substrate and low gradient shorelines.

One concern in creating an island was that newly created habitat may be ideal rearing habitat for some stages of the life cycle of predator fishes. Based on subadult and adult abundance of predator fishes and results from larval fish sampling, both in shoreline and adjacent pelagic water, abundance has not increased as a result of in-water disposal. We have observed increased smallmouth bass abundance,

although that increase is probably related to more stable water levels and low flows in the Snake River.

Use of dredged material for habitat enhancement in Lower Granite Reservoir seems realistic from results to date. We have not observed higher catch rates of predator fishes at disposal stations than at reference stations. The benthic community has remained low in abundance at the two island disposal stations, although substantial increases have occurred at the mid-depth plateau that was created in 1988, one year before the island was constructed. Benefits of disposal seem to be in providing suitable rearing habitat for age-0 chinook salmon and probably increasing the availability of food for downstream migrating yearling and age-0 rearing salmonids.

INTRODUCTION

Sediment deposition in Lower Granite Reservoir, Idaho-Washington, has concerned managers over the ability of the levee system on the Snake and Clearwater rivers to protect the cities of Lewiston, Idaho and Clarkston, Washington. Estimates of sediment deposition by U.S. Army Corps of Engineer personnel have indicated that nearly 3 million cubic yards annually enter the confluence of the Snake and Clearwater rivers at the upper end of Lower Granite Reservoir.

A number of alternatives are being evaluated to alleviate the accumulation of sediment, although dredging and in-water disposal are immediate short-term solutions and are the focus of this multi-year study. Experimental in-water disposal approximately 19 miles (30.6 km) downstream of the confluence of the Snake and Clearwater rivers was conducted during 1988 and 1989. Dredge material was used to create an island and an underwater plateau at mid-depth (20-60 ft; 6.1-18.3 m) located at river mile 119.5 (RM 119.5).

Historically, dredged material has been considered a liability. Use of dredged material, however, can be beneficial under the right conditions. Shallow water habitat only constitutes about 10% of the surface area in Lower Granite Reservoir. The importance of shallow water habitat in Lower Granite Reservoir has been attributed to short-term foraging by yearling anadromous fishes, such as chinook salmon *Oncorhynchus tshawytscha*, steelhead trout *O. mykiss* and early rearing by subyearling chinook salmon (Bennett and Shier 1986; Bennett et al. 1988, 1990, 1993). In 1990, Bennett et al. (1993) found that about 10% of all

subyearling chinook salmon collected in Lower Granite Reservoir were collected from shorelines adjacent to Centennial Island which was created in 1989.

Fishery managers are concerned with in-water disposal and the potential for increased abundance of predators as a result of providing suitable habitat for their production. Initial findings have indicated that catch rates of larval and juvenile predators at experimental disposal sites have not been elevated above those at reference sites (Bennett et al. 1989, 1990, 1993). A majority of the larval northern squawfish rearing occurs in the upper part of Lower Granite Reservoir near RM 135, and numbers collected from experimental in-water disposal stations have generally been statistically ($P < 0.05$) similar to those at reference stations (Bennett et al. 1993).

As a result of these concerns over potential habitat and aquatic community changes, this project was funded as a continuation of the in-water disposal evaluation.

OBJECTIVES

1. To monitor abundance of larval, juvenile and adult predators with special emphasis on northern squawfish at in-water disposal sites and compare with those of reference sites;

2. To assess white sturgeon abundance and habitat factors associated with their abundance in Lower Granite Reservoir;

3. To estimate juvenile salmonid fish consumption by northern squawfish in Lower Granite Reservoir;

4. To assess age-0 chinook salmon abundance in Lower Granite Reservoir and assess the potential suitability of the disposal sites for rearing of age-0 chinook salmon; and

5. To compare benthic community structure and abundance at disposal and reference sites.

STUDY AREA

Ten sampling stations in Lower Granite Reservoir were used to monitor fish abundance during 1991 (Figure 1). Stations 1, 2 and 4 were in areas created by in-water disposal of dredged material. Stations 3, 5, 9 and 10 were classified as shallow water reference stations. One additional reference station (11) was sampled for larval predator abundance. Not all stations were sampled to fulfill each stated objective. Also, 22 stations were sampled to assess the relative abundance of age-0 chinook salmon (Objective 4; Figure 2). Specific locations of sampling stations were as follows:

Station	Location
1	RM 120.48-120.19 shoreline adjacent to the island created with dredge materials;
2	RM 120.48-120.19 open water shoreline adjacent to island created with dredge materials;
3	RM 120.48-120.19 reference station with shoreline area inside the mid-depth site (on-shore);
4	RM 120.48-120.19 mid-depth disposal site that created the underwater bench;
5	RM 127.0 shallow water reference site (SR2S in Bennett and Shrier 1986; LG2S in Bennett et al. 1988);
6	RM 111.3-112.0 mid-depth reference site (LG1M in Bennett et al. 1988);
8	RM 120.5 deep water reference site;
9	RM 111.0 shallow water reference site (LG1S in Bennett et al. 1988);
10	RM 110.0 shallow water reference site on the south side of the reservoir;
11	RM 135.0 shallow water reference site on the north side of the reservoir (LG5S in Bennett et al. 1988);

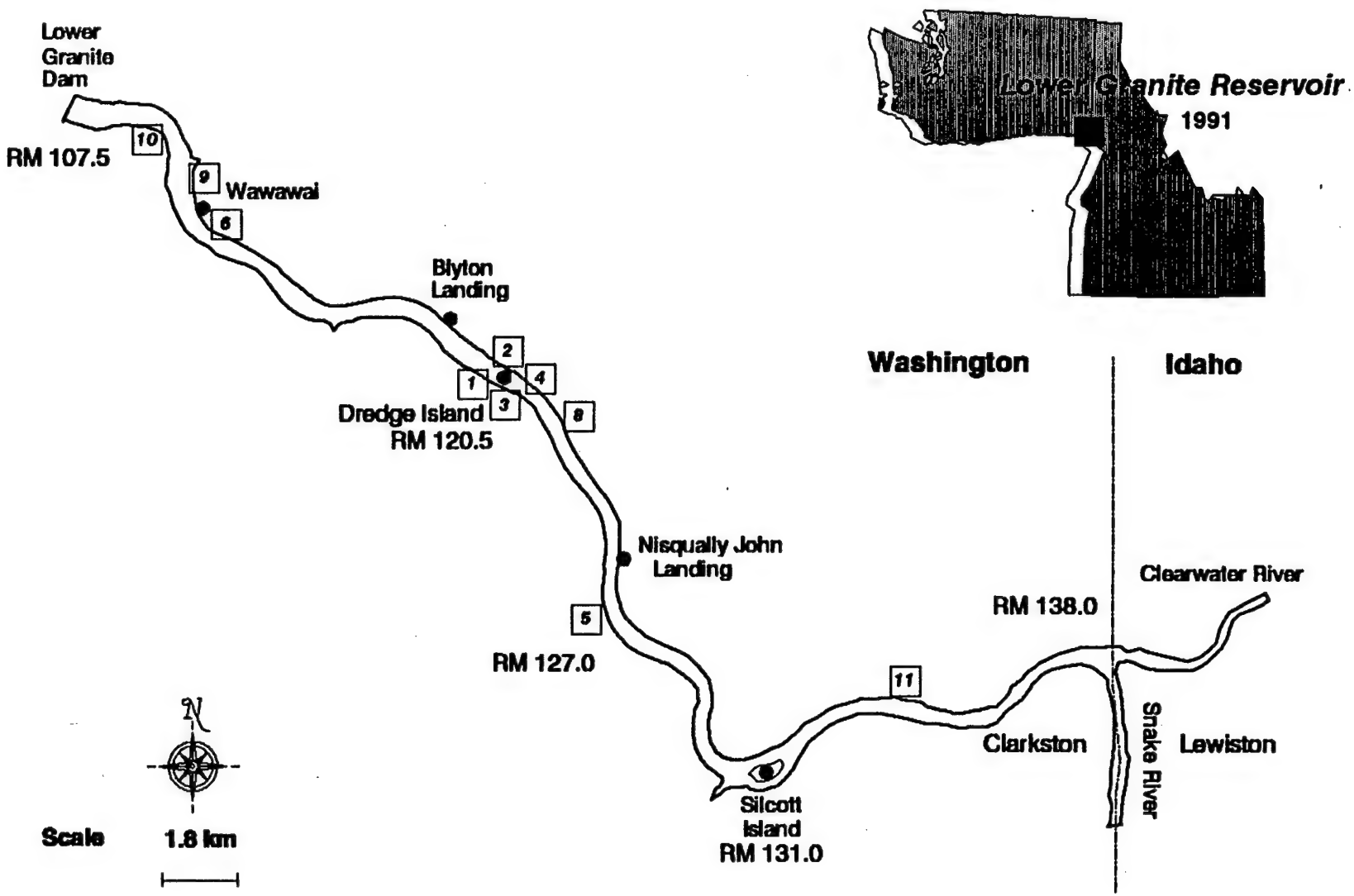


Figure 1. Sampling locations in Lower Granite Reservoir, Idaho-Washington where adult, subadult, juvenile and larval fish abundance was assessed during spring, summer and fall 1991.

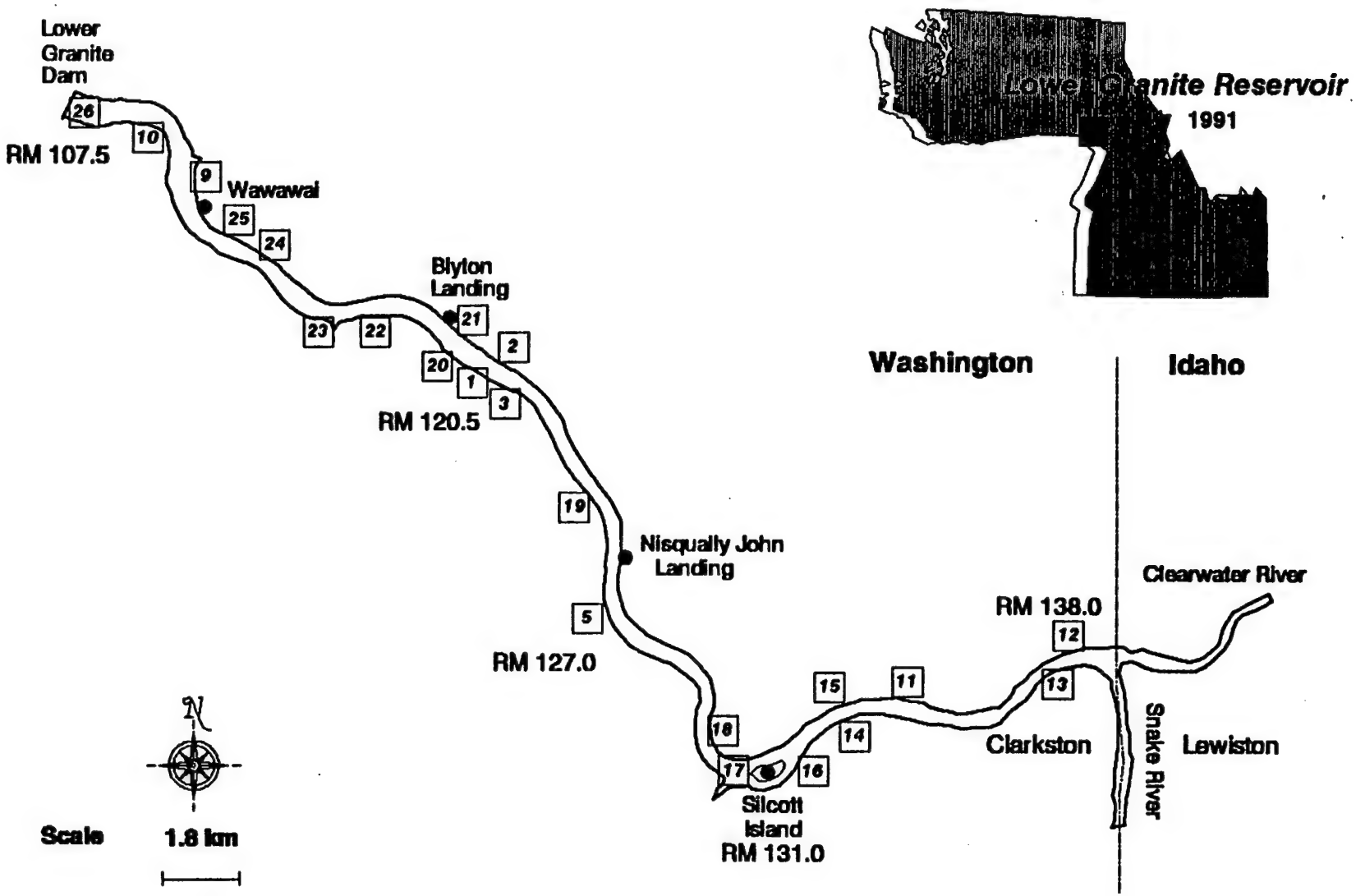


Figure 2. Locations in Lower Granite Reservoir, Idaho-Washington where juvenile chinook salmon sampling was conducted at biweekly intervals during spring 1991.

12 RM 138.0 south shoreline 1 mile upstream from Red Wolf Crossing; age-0 chinook beach seining station;

13 RM 137.5 south shoreline 0.5 miles upstream of the Red Wolf Bridge crossing; age-0 chinook beach seining station;

14 RM 132.6 south shoreline 1.6 miles upstream from Silcott Island; age-0 chinook beach seining station;

15 RM 132.5 rip-rap north shoreline; age-0 chinook beach seining station;

16 RM 132.1 south shoreline; age-0 chinook beach seining station;

17 RM 131.0 Silcott Island (Chief Timothy State Park); age-0 chinook beach seining station;

18 RM 129.0 one mile upstream from Steptoe Canyon embayment; age-0 chinook beach seining station;

19 RM 123.25 west shoreline 2.0 miles downstream from Nisqually John Landing; age-0 chinook beach seining station;

20 RM 119.5 west shoreline 0.5 miles downstream and across from Blyton Landing; age-0 chinook beach seining station;

21 RM 119.0 upstream shoreline adjacent to Blyton Landing; age-0 chinook beach seining station;

22 RM 117.0 Keith Canyon 1.1 miles upstream from Knoxway Canyon Bay; age-0 chinook beach seining station;

23 RM 115.9 Knoxway Canyon Bay; age-0 chinook beach seining station;

24 RM 114.8 Crum boat landing 0.9 miles upstream from Granite Point; age-0 chinook beach seining station;

25 RM 112.75 northeast shoreline 0.75 miles downstream from Granite Point; age-0 chinook beach seining station; and

26 RM 107.5 Lower Granite Dam and Lock; age-0 chinook beach seining station.

A systematic gill net survey of 20 hydroacoustic transects used by Biosonics Inc. in 1989 to quantify fishes in Lower Granite Reservoir (Bennett et al. 1990; Thorne et al. 1992) was sampled to assess relative white sturgeon abundance. Preliminary information collected from the systematic gill net survey identified main channel and bench areas with low and high concentrations of sturgeon. Nine transects between RM 110.5 and RM 137.1 were randomly selected for additional gill net and setline sampling to compare locations with varying concentrations of sturgeon and associated habitat (Figure 3). Transect locations were as follows:

Transect	Location
R1S11	RM 110.5 transect 0.5 miles downstream of Wawawai Landing;
R1S29	RM 116.5 transect 1.4 miles upstream of Knoxway Canyon Bay;
R2S2	RM 117.7 transect 2.5 miles upstream of Knoxway Canyon Bay;
R2S8	RM 119.9 transect 0.5 miles upstream of Blyton Landing;
R2S17	RM 127.0 transect 1.5 miles upstream of Nisqually John Landing;
R3S4	RM 129.2 transect 3.7 miles upstream of Nisqually John Landing;
R3S7	RM 131.6 transect 2.4 miles downstream from Port of Wilma;
R3S9	RM 133.7 transect 0.5 miles downstream from Port of Wilma; and
R3S12	RM 137.1 transect 0.2 miles downstream from Red Wolf Bridge.

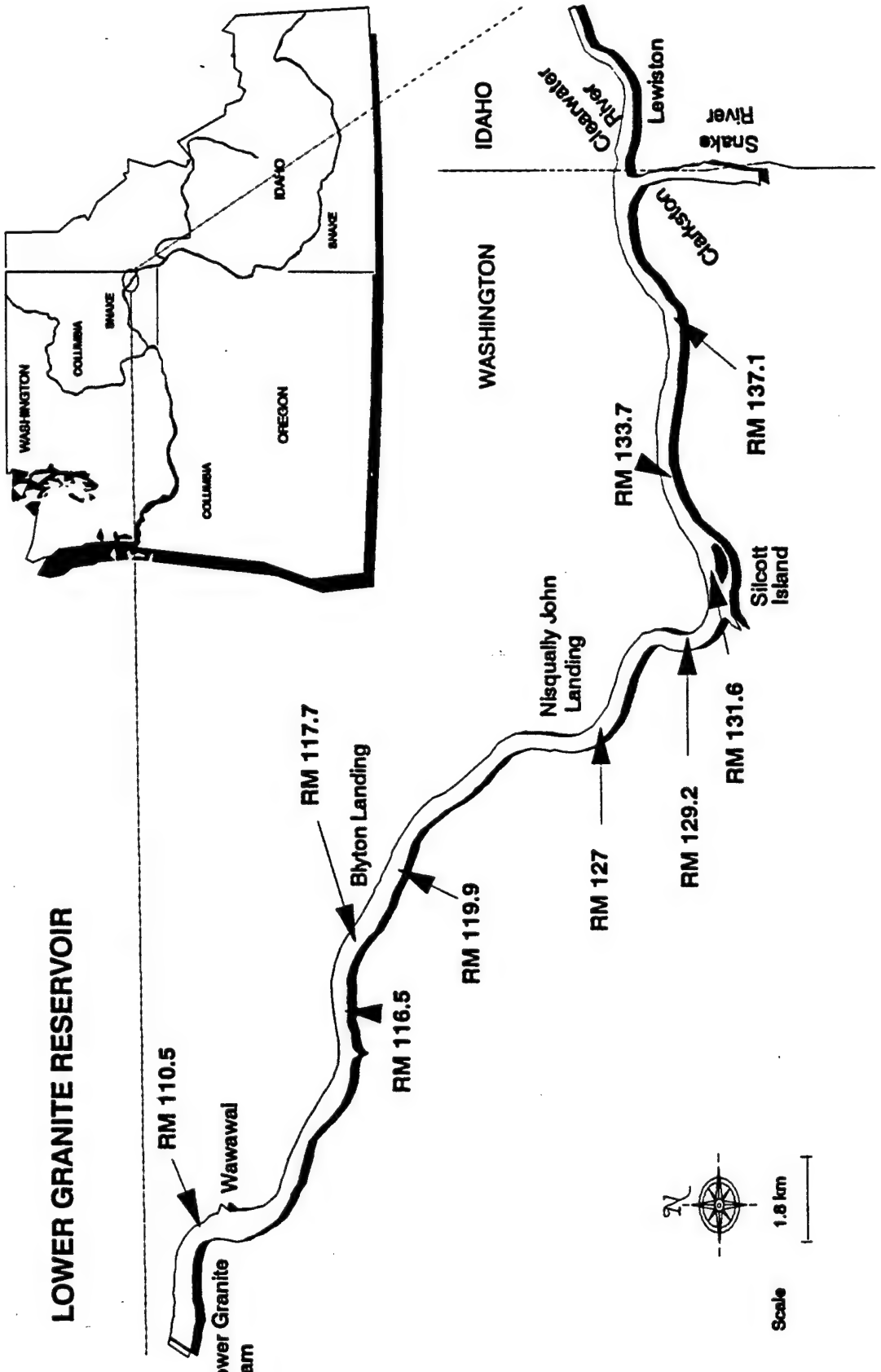


Figure 3. Sampling locations for white sturgeon in Lower Granite Reservoir, Idaho-Washington during 1991.

Objective 1: To monitor abundance of larval, juvenile and adult predators with special emphasis on northern squawfish at in-water disposal sites and compare with those of reference sites.

METHODS

To reduce sampling gear bias and maximize collection efficiency in a variety of habitats, several gear types were used during 1991 to make representative collections in Lower Granite Reservoir (D. Arthaud 1992). Gear types included gill nets, beach seines, electrofishing, surface trawling, and half-meter plankton nets and a handbeam trawl. Gill nets were used to assess the relative abundance of potential predators and white sturgeon in pelagic waters. Surface trawling was used to sample pelagic salmonid abundance. Beach seining and electrofishing were used to sample shallow water stations during diurnal and nocturnal hours, respectively. Plankton nets and a beam trawl were used to estimate larval predator abundance.

Eight horizontal multifilament gill nets 225 ft x 6 ft (68.6 m x 1.2 m), consisting of three graded panels with bar measurements of 1.5, 1.75 and 2.0 inches (3.1, 4.1 and 5.1 cm; Webb et al. 1987), were fished at stations 1, 2, 3, 4, 5, 6 and 8 during April, May, June, August and October. Gill nets were set perpendicular to the shoreline and fished on the bottom for approximately 3 hours of daylight and 3 hours of dark for a total of 6 hours. We have found that catches are generally higher during the evening crepuscular period than other times during the day and night (Bennett et al. 1988). Gill nets were checked every 2 hours at stations 1, 2, 3, 4 and 5 to avoid destructive sampling to salmonids and other fish species. A 3-hour schedule was used at mid-depth (6) and deep (8) water reference stations because few salmonids were collected

at these stations during previous sampling efforts. As in 1990, gill nets were numbered to further refine estimates of fish abundance. Individual numbering of the nets enabled us to use the net as a sampling unit compared to a net night used in previous surveys (Bennett et al. 1988).

A 100 ft x 8 ft (30.5 m x 2.4 m) beach seine with a 8 x 8 x 8 ft (12.1 m^3) bag constructed of 0.25 inch mesh (0.64 cm) was used to sample fish along the shoreline at shallow water stations 1, 2, 5, 9 and 10 (Figure 1) at biweekly intervals during April, May and June and at monthly intervals during July, August, September and October. Standardized beach seine hauls were made by setting the seine parallel and approximately 50 ft (15.2 m) from shore with attachment lines, and then the seine was drawn perpendicular toward the shoreline. An area equivalent to 5,000 ft^2 (1,500 m^2) was sampled each haul.

Standardized nighttime electrofishing was conducted by paralleling the shoreline, as close as possible, at shallow water stations 1, 2, 3, 5, 9 and 10 (Figure 1). Biweekly sampling efforts were conducted during April, May and June and at monthly intervals during July through October. Electrofishing effort generally consisted of three periods of 5 minutes at each station. At disposal stations 1 and 2, two periods of 5 minutes at each station were used because of their small size. A constant output of 400 volts at 3-5 amps was found to adequately stun fish without causing mortality or visual evidence of injury.

Surface trawling was used to sample stations 2, 4, 5 and 6 (Figure 1) at biweekly intervals during April, May and June. Two hauls per site

were taken using a 32.8 ft (10 m) surface trawl consisting of 1.5 inch (3.8 cm) mesh netting with a cod end of 0.25 inch (0.64 cm) mesh. The surface trawl was towed between two boats, approximately 145 ft (45 m) apart, the length of each station at an average speed of approximately 1.2 ft/s (0.4 m/s).

All fish collected by the various gear types were identified to species and measured to total length (mm), except fishes that were released immediately without being removed from the water.

Larval fish sampling was conducted biweekly from mid-June through mid-August, the time of maximum larval predator abundance in Lower Granite Reservoir (Bennett et al. 1993). To assess larval predator abundance in pelagic waters at disposal stations 1, 2 and 4 and shallow water reference stations 5 and 11, paired plankton nets were employed. Half-meter plankton nets were towed at night approximately 5.25 ft/s (1.5 m/s) immediately below the surface and 3.3 ft (1.0 m) deep for 3 minutes at each depth. Three paired hauls were taken at each station, providing six samples/station/sampling date. A custom built, hand-drawn, beam trawl (LaBolle 1985) was used to assess larval predator abundance in the littoral regions of shallow water disposal (1 and 2) and reference (5 and 11) stations. The beam trawl was pulled at a constant rate along the shoreline over a standard distance of 50 ft (15.2 m). Three hauls were taken in shallow (< 1 m; < 3.28 ft) and deeper (> 1 m; > 3.28 ft) water for a total of six samples/station/sampling date.

All plankton net and handbeam trawl samples were preserved in a 10% buffered formalin solution for later identification to the lowest possible taxon. Larval fishes were later sorted from detritus, insects, etc. and identified to species when possible (Bratovich 1985). The degree of larval development regulated the taxonomic level to which larva were identified.

Estimates of larval fish density were determined by using a quadrant sampling scheme (Scheafer et al. 1986) for both half-meter plankton nets and handbeam trawl samples. Mean density (M) was determined by the following:

$$\text{Density } M = \bar{N}/a$$

where: $\bar{N}$ = Mean number of fish among samples (n = 3 or n = 6),
a = Area of 1 half-meter plankton net or handbeam trawl.

Total density (T) was determined by multiplying the mean density by total volume sampled (half-meter plankton net 318.08 m^3 or handbeam trawl 68.4 m^3 or 34.2 m^3 depending on depth):

$$T = M * A$$

where: M = Mean density,
A = Total volume.

The variance (V(T)) was determined by

$$V(T) = A^2 * M/a*\bar{N}$$

where: M = Mean density,
A^2 = Square of total volume,
a = Volume of one sample,
$\bar{N}$ = Mean number of fish among samples.

The bound (β) was ($\alpha = 0.05$) calculated by

$$\beta = 2 * A\sqrt{M/a*\bar{N}}.$$

Upper and lower bounds were determined by adding and subtracting the bound from the mean density.

RESULTS

Relative Abundance

A total of 15,689 fish representing 21 species and three genera were collected at disposal (1, 2 and 4) and reference (3, 5, 6, 8, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during 1991 (Tables 1-4). The highest number of adult and subadult fish collected was from 1 April through 30 June, the spring sampling interval, when a total of 8,751 fish were collected (Table 2). A total of 4,852 fish were collected during summer (Table 3) and 2,086 fish were collected during fall (Table 4).

Largescale suckers *Catostomus macrocheilus* were the most abundant species sampled during spring 1991 accounting for 30.5% (n = 2,670) of the fish collected (Table 2). Next in abundance were juvenile chinook salmon (22.8%; n = 1,998) and smallmouth bass *Micropterus dolomieui* (13.0%; n = 1143) followed by northern squawfish *Ptychocheilus oregonensis* (8.8%; n = 773), juvenile steelhead (6.4%; n = 565) and chiselmouth *Acrocheilus alutaceus* (6.3%; n = 554).

The highest number of adult and subadult predators, smallmouth bass and northern squawfish, sampled during spring by all gear types were collected from shallow water reference station 5 (n = 426) followed by mid-depth disposal station 4 (n = 379) and shallow water reference station 10 (n = 370; Table 2). Abundance of smallmouth bass (15%) and northern squawfish (8.7%) at shallow water disposal stations 1 and 2

Table 1. List of species codes, scientific names and common names for fishes sampled in Lower Granite Reservoir, Idaho-Washington during 1991.

Codes	Scientific Name	Common Name
LTR	Entosphenus tridentatus	Pacific lamprey
ASA	Alosa sapidissima	American shad
ATR	Acipenser transmontanus	white sturgeon
ONE	Oncorhynchus nerka	sockeye salmon
OTS	Oncorhynchus tshawytscha	chinook salmon
PWI	Prosopium williamsoni	mountain whitefish
OMY	Oncorhynchus mykiss	rainbow trout
AAL	Acrocheilus alutaceus	chiselmouth
CCA	Cyprinuis carpio	carp
MCA	Mylocheilus caurinus	peamouth
POR	Ptychocheilus oregonensis	northern squawfish
RBA	Richardsonius balteatus	redside shiner
CCO	Catostomus columbianus	bridgelip sucker
CMA	Catostomus macrocheilus	largescale sucker
INA	Ictalurus natalis	yellow bullhead
INE	Ictalurus nebulosus	brown bullhead
IME	Ictalurus melas	black bullhead
IPU	Ictalurus punctatus	channel catfish
LGI	Lepomis gibbosus	pumpkinseed
LMA	Lepomis macrocheilus	bluegill
LSP	Lepomis spp.	misc. juv. sunfish
PNI	Pomoxis nigromaculatus	black crappie
PAN	Pomoxis annularis	white crappie
PSP	Pomoxis spp.	misc. juv. crappie
MDO	Micropterus dolomieui	smallmouth bass
PFL	Perca flavescens	yellow perch
COT	Cottus spp.	sculpin

Table 2. Number of fishes sampled by all gear types in Lower Granite Reservoir, Idaho-Washington during spring (1 April-30 June) 1991.

Species	Stations									TOTAL
	1	2	3	4	5	6	8	9	10	
white sturgeon							1			1
sockeye salmon	1							7		8
chinook salmon	70	163	113	376	996	78		194	8	1,998
mountain whitefish	29	10	11	7	4					61
rainbow trout	39	64	41	16	279	73	1	43	9	565
chiselmouth	46	37	77	78	146	7	1	77	85	554
carp			4		5	3				12
peamouth	30	1	6	7	10					54
northern squawfish	37	30	66	251	295	32	13	4	45	773
redside shiner	2		1		1				3	7
bridgelip sucker	2	6	17	11	16	1		26	8	87
largescale sucker	313	331	415	317	539	15	10	421	309	2,670
yellow bullhead			1	1	2				1	5
brown bullhead	2			1	7					10
black bullhead				3	4					7
channel catfish	1				1	6	3			11
pumpkinseed	5	1	11	25	29	1		23	89	184
bluegill	5		2	1	1			4	10	23
Lepomis sp.	13	5	20	12	12			9	357	428
black crappie	7	9	11	9	12			3	11	62
white crappie	4	4	10	2	12	5		6	5	48
Pomoxis sp.	1		1						7	9
smallmouth bass	104	71	121	128	131	1		262	325	1,143
yellow perch	1	1	3	7	10					22
sculpin				4	4			1		9
TOTALS	712	733	931	1,256	2,516	222	29	1,080	1,272	8,751

Table 3. Number of fishes sampled by all gear types in Lower Granite Reservoir, Idaho-Washington during summer (1 July-30 September) 1991.

Species	Stations						TOTAL
	1	2	3	5	9	10	
rainbow trout					1		1
chiselmouth	6		7	10	3	3	29
carp	5		8		2		15
peamouth	12	1	10	9	2		34
northern squawfish	253	10	115	91	25	49	543
bridgelip sucker			1	1	11	12	25
largescale sucker	91	62	278	32	124	53	640
yellow bullhead			5	1	8		14
brown bullhead	6		1				7
pumpkinseed	13	4	30	19	52	25	143
bluegill	1	1	6	5	12	8	33
Lepomis sp.	25		1,356	5	1	3	1,390
black crappie	1		11	3			15
white crappie	7	16	78	3	7	3	114
Pomoxis sp.	14	2	497	30		1	544
smallmouth bass	142	123	225	173	384	258	1,305
TOTALS	576	219	2,628	382	632	415	4,852

Table 4. Number of fishes sampled by all gear types in Lower Granite Reservoir, Idaho-Washington during fall (1 October-31 October) 1991.

Species	Stations									TOTAL
	1	2	3	4	5	6	8	9	10	
white sturgeon		1					2			3
chinook salmon		1			1					2
rainbow trout	1	7	4	3	3	1		2	1	22
chiselmouth	2	3	5	4	7	1				22
carp			5	3	1	1	5			15
peamouth	6	1		4	3	2				16
northern squawfish	76	23	65	10	63	19	15	7	15	293
brigdelip sucker	18	3	6		3	1		11	4	46
largescale sucker	162	114	119	30	143	49	29	41	29	716
yellow bullhead	2	3	2		1					8
brown bullhead	3	5	5	1	7	7				28
black bullhead	2									2
channel catfish	4				4	4	9			21
pumpkinseed		1	22	1	8			12	3	47
bluegill								2		2
Lepomis sp.	77	4	224		21			4	49	379
black crappie					3	7			1	11
white crappie	5	2	25	1	13					46
smallmouth bass	21	29	187	5	70	6		63	19	400
yellow perch					5	2				7
TOTALS	379	197	669	62	356	100	60	142	121	2,086

were low and similar. Fish collected during spring were sampled by gill netting, beach seining, electrofishing and surface trawling.

During the summer 1991 sampling interval, 1 July through 30 September, a total of 4,852 fish were sampled by all gear types. *Lepomis* spp. dominated the catch (28.6%) followed closely by smallmouth bass (26.9%) and distantly by largescale suckers (13.2%), *Pomoxis* spp. (11.2%) and northern squawfish (11.1%; Table 3). Catches of juvenile salmon and juvenile steelhead were low.

The highest number of smallmouth bass and northern squawfish were collected from shallow water reference station 9 (n = 409) and shallow water disposal station 1 (n = 395). The number of predators collected at disposal station 2 was low (n = I33). Fish collected during the summer sampling interval were collected by daytime beach seining and nighttime electrofishing, as no gill netting was conducted.

A total of 2,086 fish were collected by all gear types during the fall 1991 sampling interval from 1 October through 31 October (Table 4). Largescale suckers (34.3%) dominated the catches and were followed by smallmouth bass (19.2%), *Lepomis* spp. (18.2%) and northern squawfish (14.0%).

Numbers of smallmouth bass and northern squawfish collected during fall were highest at shallow water reference station 3 (n = 252) followed by reference station 5 (n = 133) and shallow water disposal station 1 (n = 97).

Length Comparisons

Spring

The majority of fish sampled in Lower Granite Reservoir during spring 1991 were between 50-500 mm (Figures 4 and 5). Length distributions at shallow water disposal stations 1 and 2 were similar to those at shallow water reference stations 3, 5, 9 and 10. Modal lengths at disposal stations 1 and 2 and reference stations 3 and 9 generally were $\geq$ 100 mm. Length distributions at mid-depth (4) disposal and reference (6) stations were similar, as modal lengths were 150 mm. Length distributions at station 6 ranged from 125-500 mm whereas those at station 4 ranged from 100-475 mm. Fish collected at deep water reference station 8 were larger (225-775 mm) as sturgeon were commonly caught there.

Summer

Length distributions during summer 1991 were generally similar to those of spring for most stations (Figure 6). Shallow water disposal and reference stations generally had an abundance of fish between 50-100 mm. Modal lengths at shallow water disposal stations 1 and 2 were 50 mm and 150 mm, respectively, compared to 75 mm and 75-100 mm during spring 1991. Modal lengths at shallow water reference stations 9 and 10 were 125 mm and 100 mm, respectively. Mid-depth disposal (4) and mid-depth (6) and deep water (8) reference stations were not sampled during summer 1991.

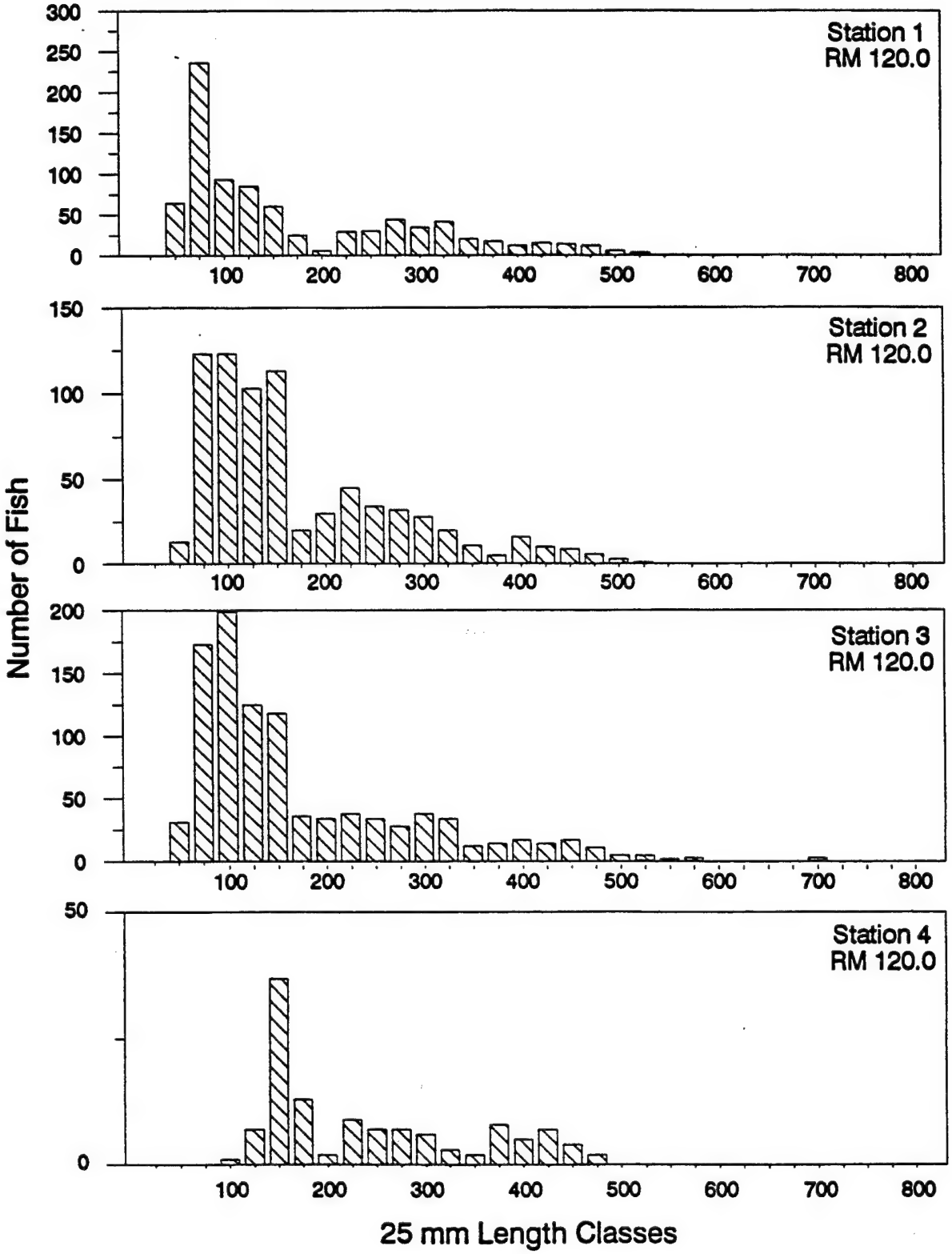


Figure 4. Length distributions of fish sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

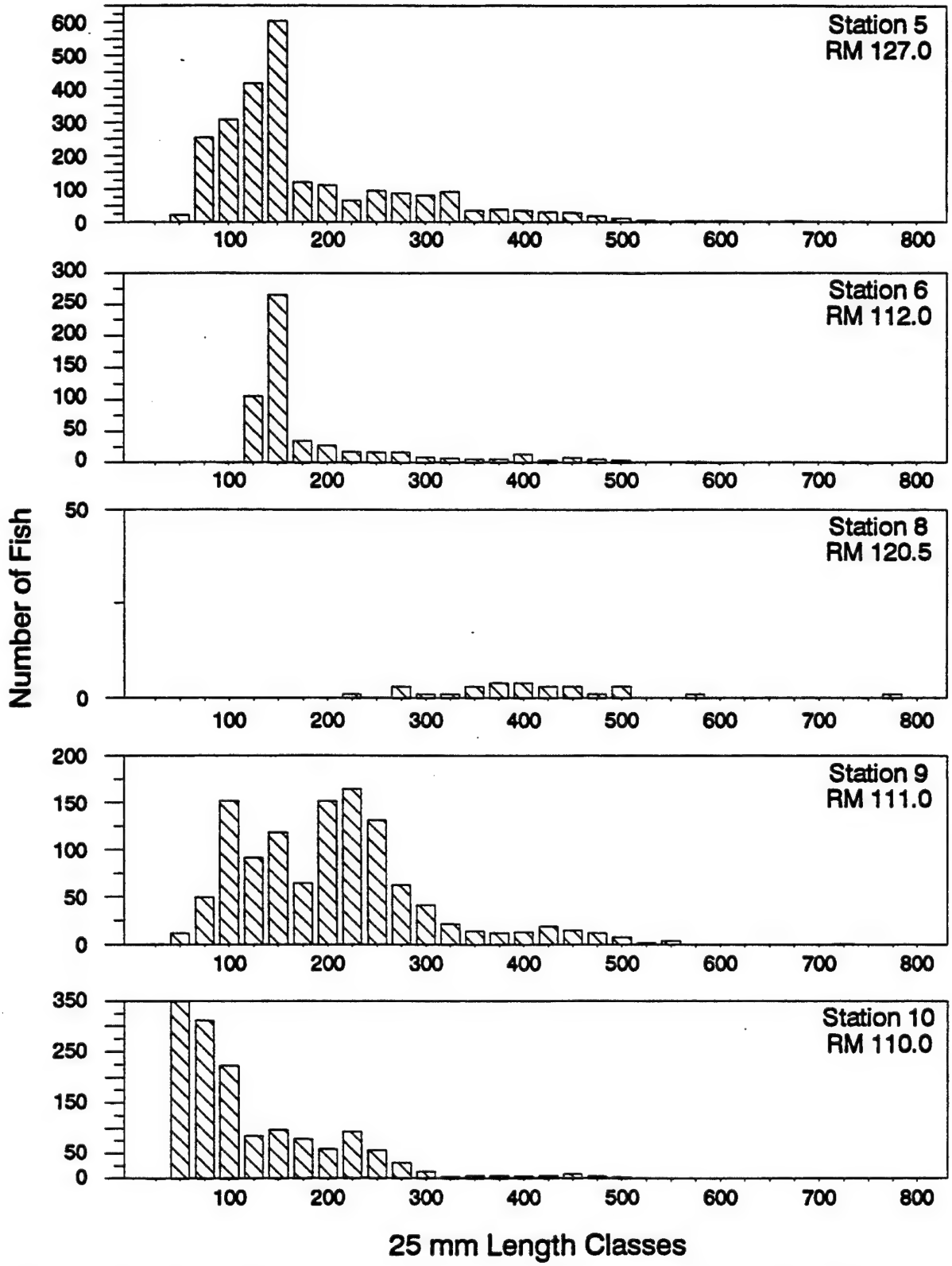


Figure 5. Length distributions of fish sampled by all gear types at shallow (5, 9 and 10), mid-depth (6) and deep (8) water reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

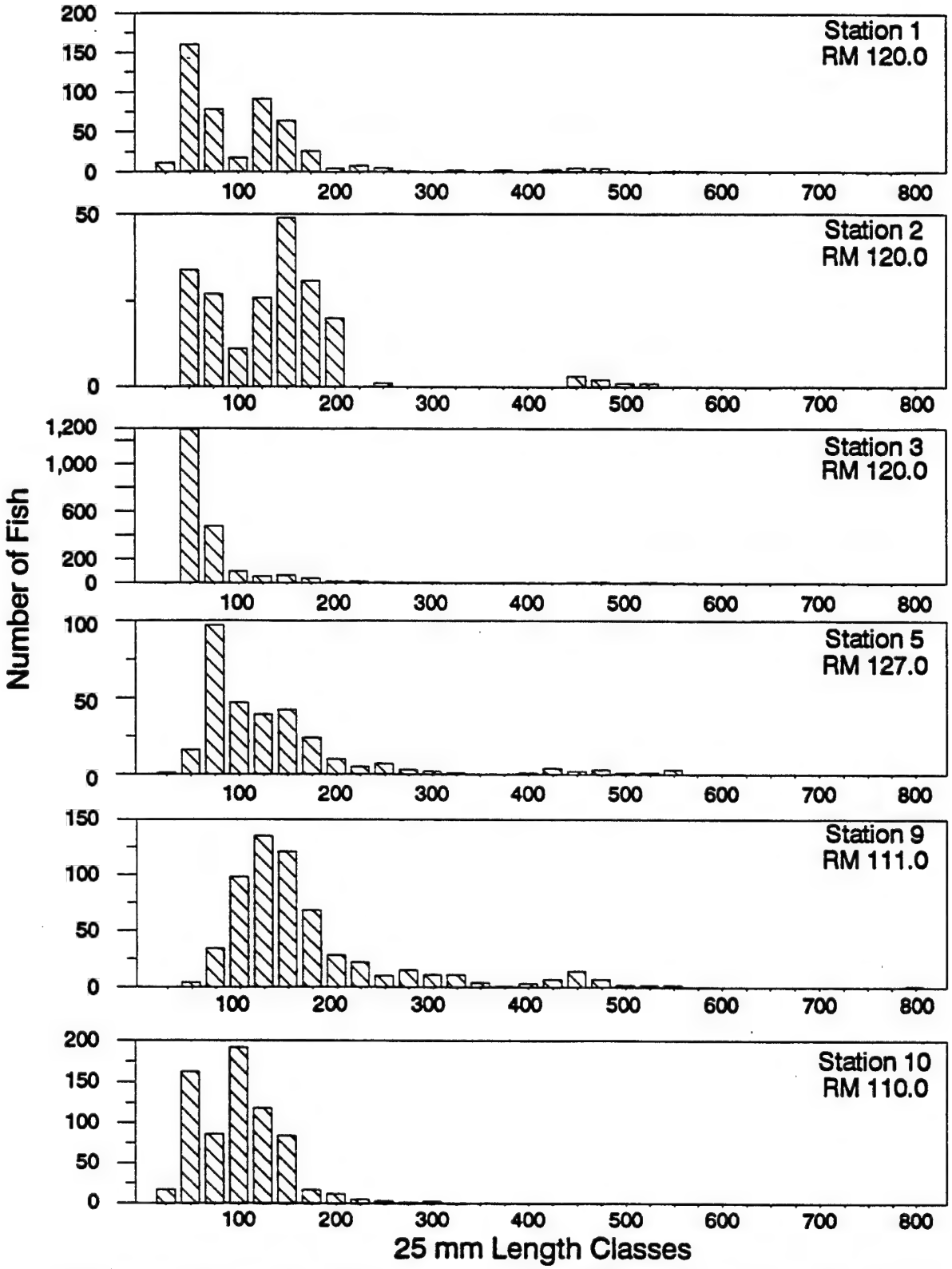


Figure 6. Length distributions of fish sampled by all gear types at shallow water disposal (1 and 2) and reference (3, 5, 9 and 10) stations during summer 1991 in Lower Granite Reservoir, Idaho-Washington.

Fall

The majority of fish sampled in Lower Granite Reservoir during fall 1991 were generally between 25-100 mm total length, although fish up to 900 mm were sampled (Figures 7 and 8). Shallow water disposal (1 and 2) and reference (3, 5 and 10) stations had similar length distributions with modal lengths of 50-75 mm, while station 9 at a modal length of 175 mm. Length distributions at mid-depth reference station 6 ranged from 175-675 mm with a modal length of 325 mm and deep water reference station 8 had primarily larger fish (300-900 mm). Smaller fish were generally not sampled at stations 6 and 8, possibly because gill nets were the only gear used to sample these stations.

Length Structure

Length structure of the key species in Lower Granite Reservoir; yearling and subyearling chinook salmon, steelhead trout, northern squawfish, channel catfish, smallmouth bass and white sturgeon were compared among stations for all gear types combined. Length structure of fishes sampled during 1991 were compared within season and gear types (Appendix Figures 1-10).

Spring

Chinook salmon.- During spring 1991, modal length of yearling and subyearling chinook salmon collected by all gear types was 150 mm (Figures 9 and 10). Although numbers varied among stations, length

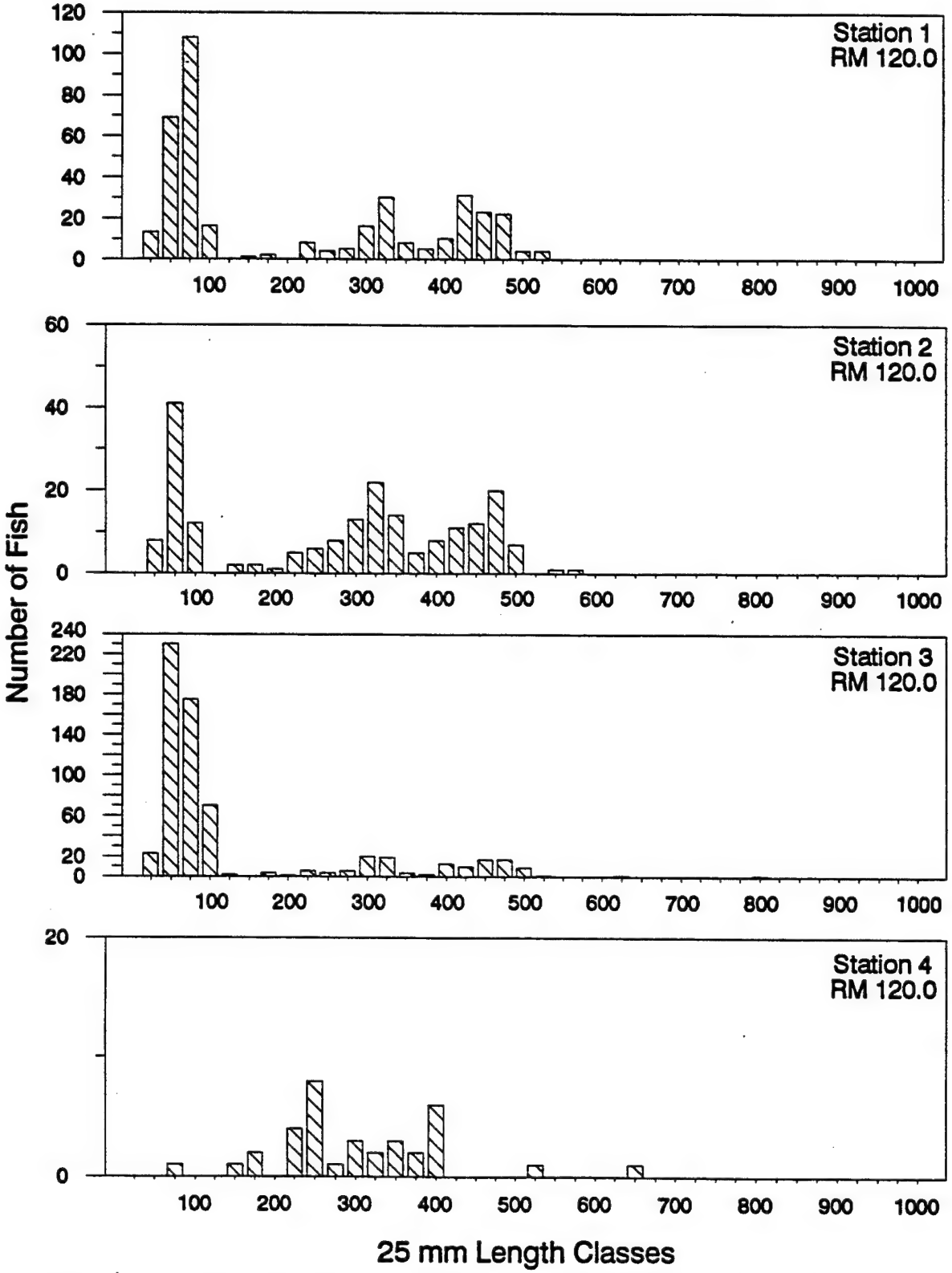


Figure 7. Length distributions of fish sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

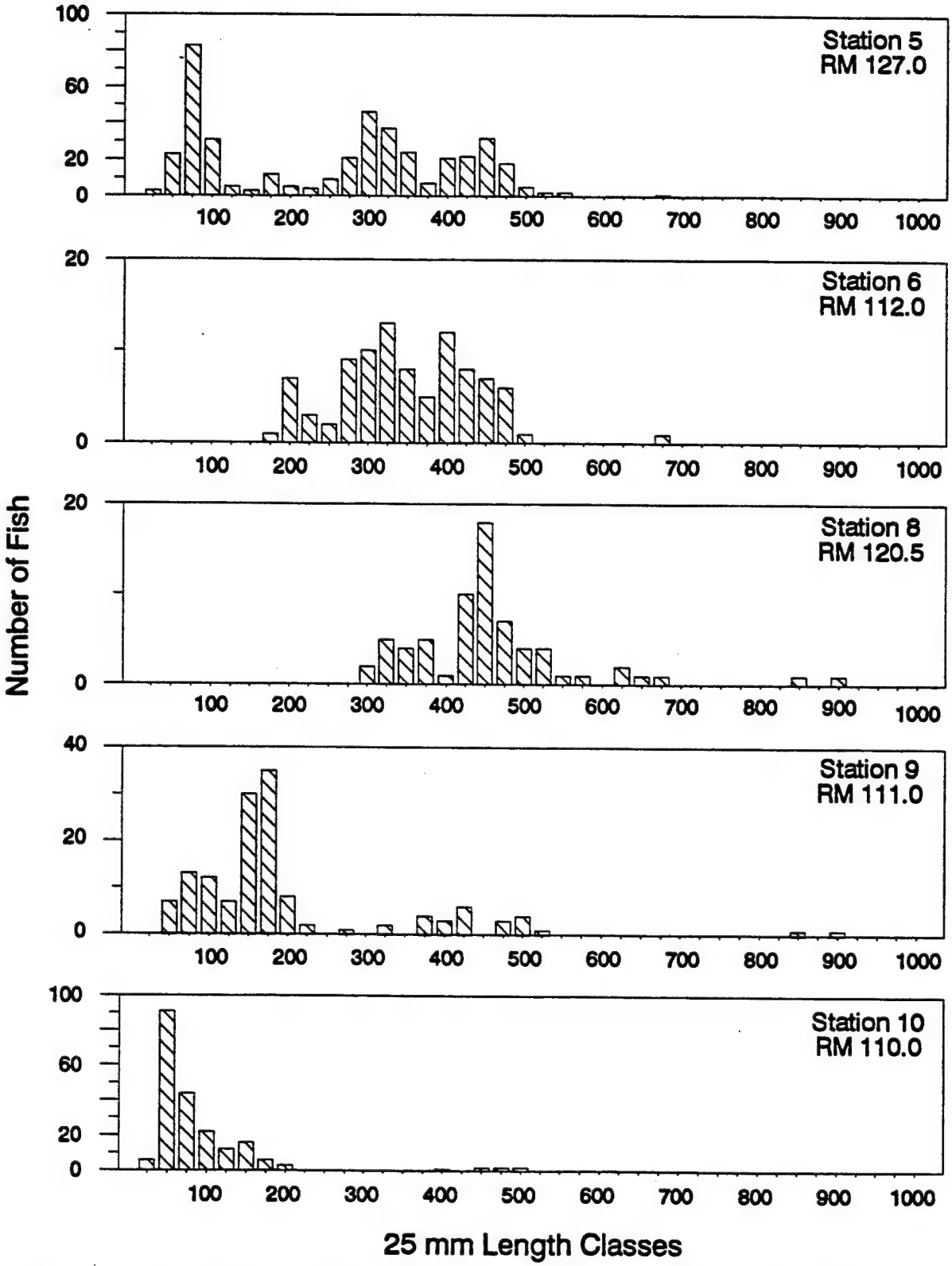


Figure 8. Length distributions of fish sampled by all gear types at shallow (5, 9 and 10), mid-depth (6) and deep (8) water reference stations during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

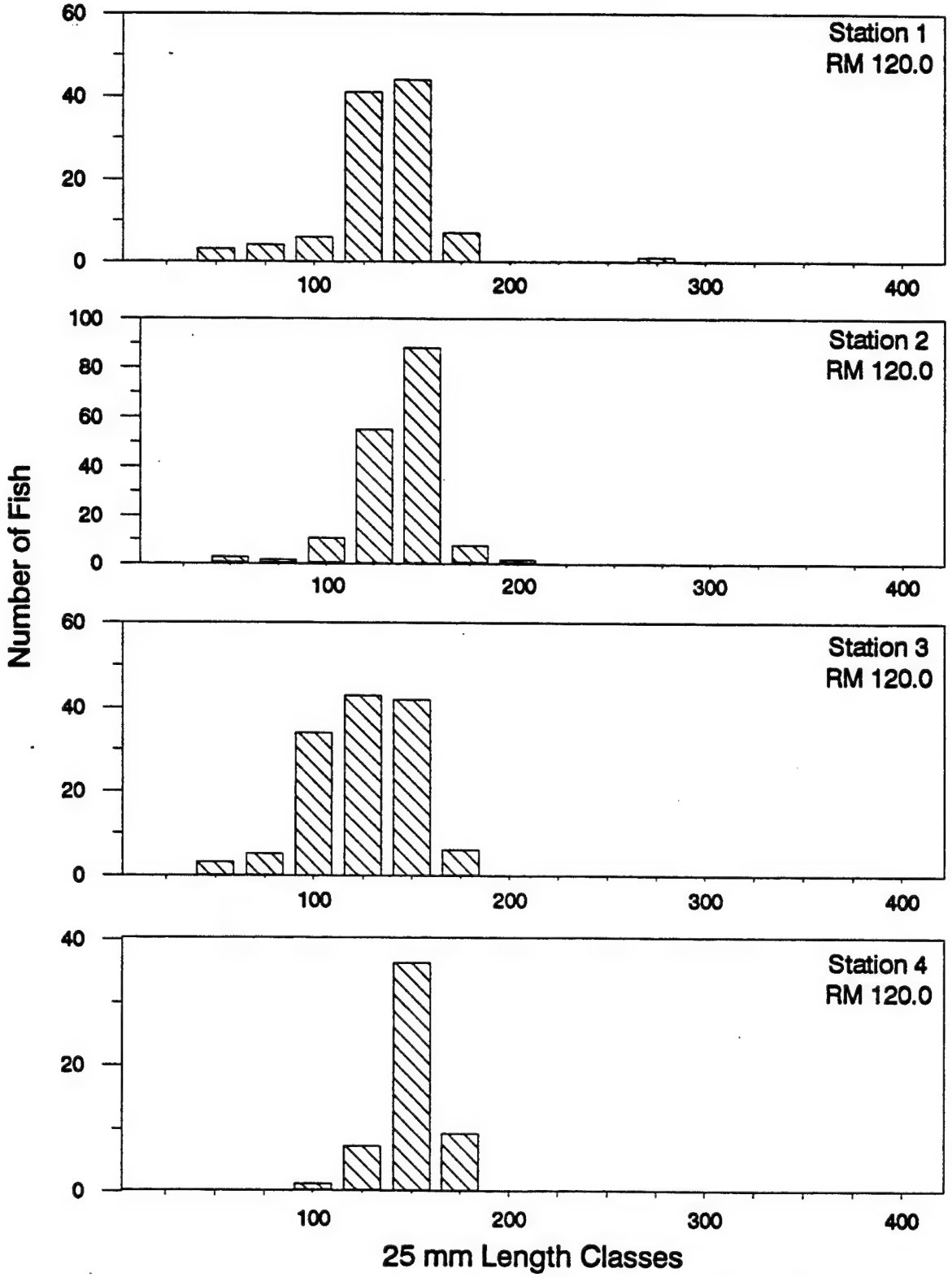


Figure 9. Length distributions of juvenile chinook salmon sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

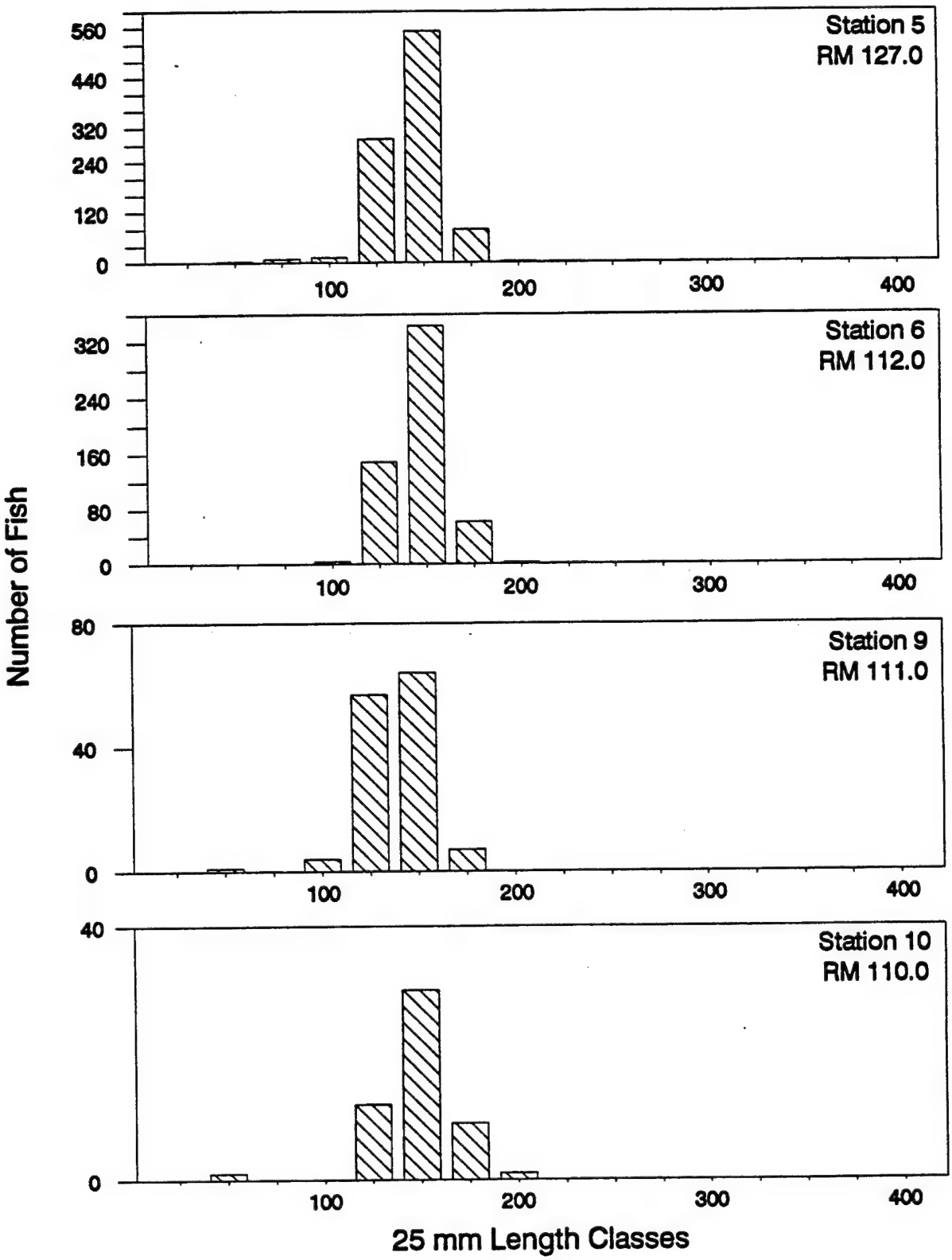


Figure 10. Length distributions of juvenile chinook salmon sampled by all gear types at mid-depth (6) and shallow water (5, 9 and 10) reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

distributions were similar. The smallest chinook sampled was in the 50 mm length class.

Steelhead.- Yearling steelhead collected by all gear types ranged in lengths from 25-325 mm (Figures 11 and 12). Modal length was 200-225 mm at shallow water disposal (2 and 4) and reference (3, 5 and 10) stations and mid-depth reference station 6. The modal lengths at shallow water disposal station 1 and shallow water reference station 9 were 275 mm. The smallest juvenile steelhead (25 mm) was collected at shallow water reference station 9.

Northern squawfish.- Length distributions of northern squawfish were similar at disposal (1 and 2) and reference (3, 5 and 10) stations (Figures 13 and 14). The range of length classes collected by all gear types during spring was 50-550 mm. Modal length classes were $\leq$ 100 mm at most shallow water stations. Several northern squawfish were caught at disposal stations 1 and 2 and ranged in length from 50-475 mm, while those at reference stations 6 and 8 ranged from 250-575 mm. Shallow water reference station 5 had the highest abundance of northern squawfish sampled.

Smallmouth bass.- Length distributions of smallmouth bass collected by all gear types during spring were similar between disposal (1 and 2) and reference (3, 5, 9, and 10) stations (Figures 15 and 16). Two distinct length classes of smallmouth bass were found at stations 1, 2, 3, 5 and 10 at $\leq$ 100 mm and 200-300 mm. Few smallmouth bass were collected at mid-depth disposal station 4 and mid-depth reference

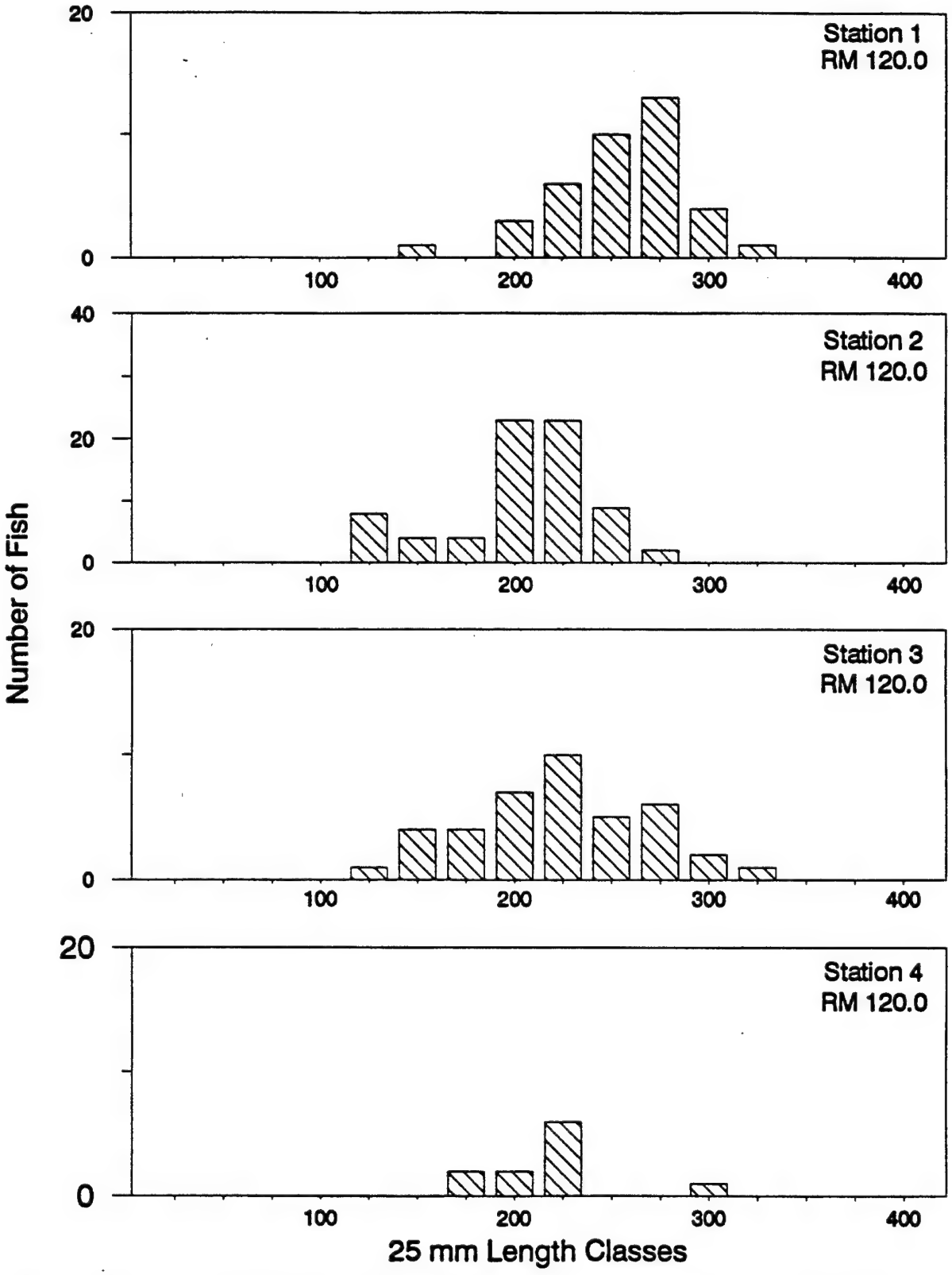


Figure 11. Length distributions of juvenile steelhead sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

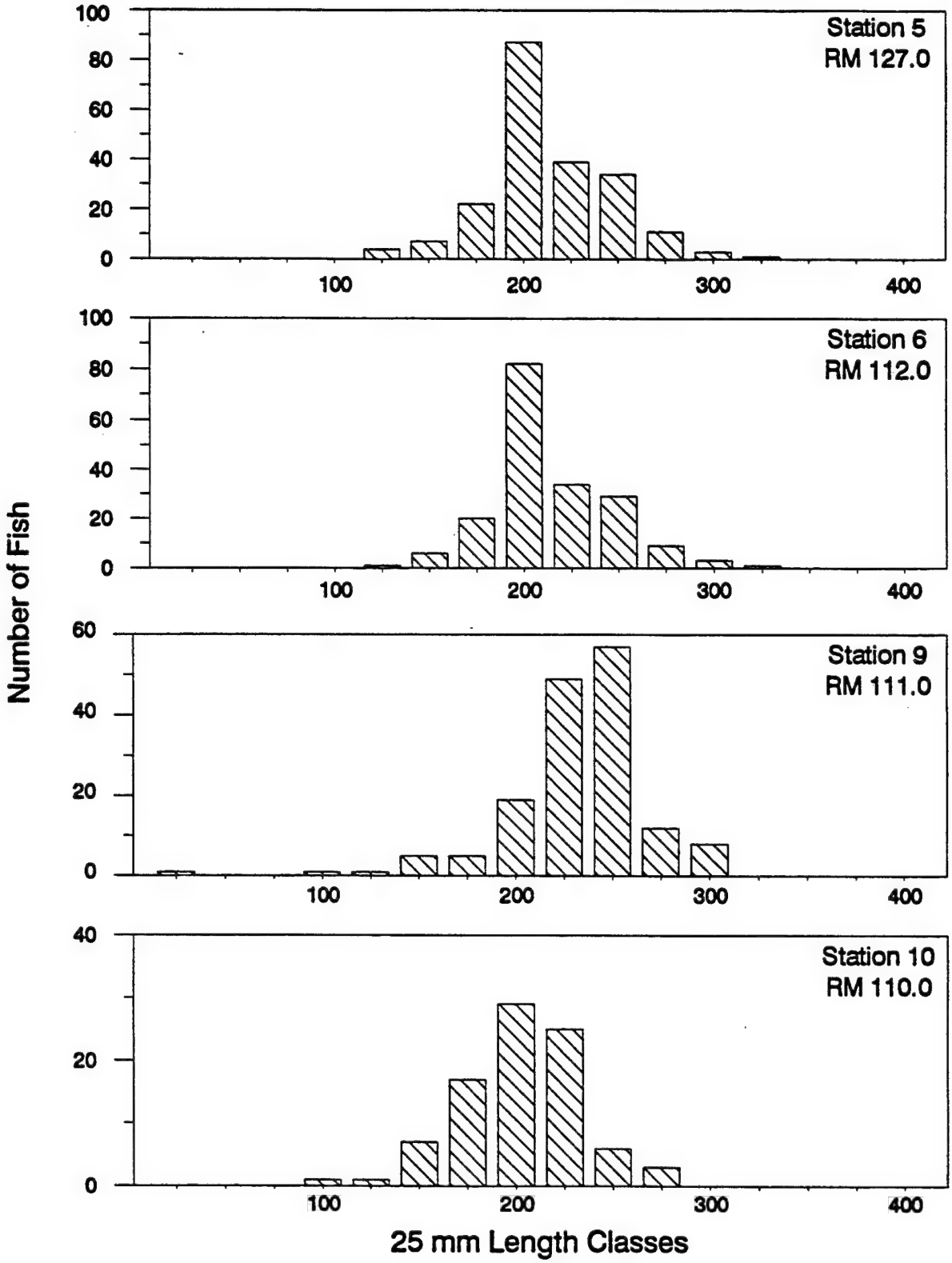


Figure 12. Length distributions of juvenile steelhead sampled by all gear types at shallow (5, 9 and 10) and mid-depth (6) reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

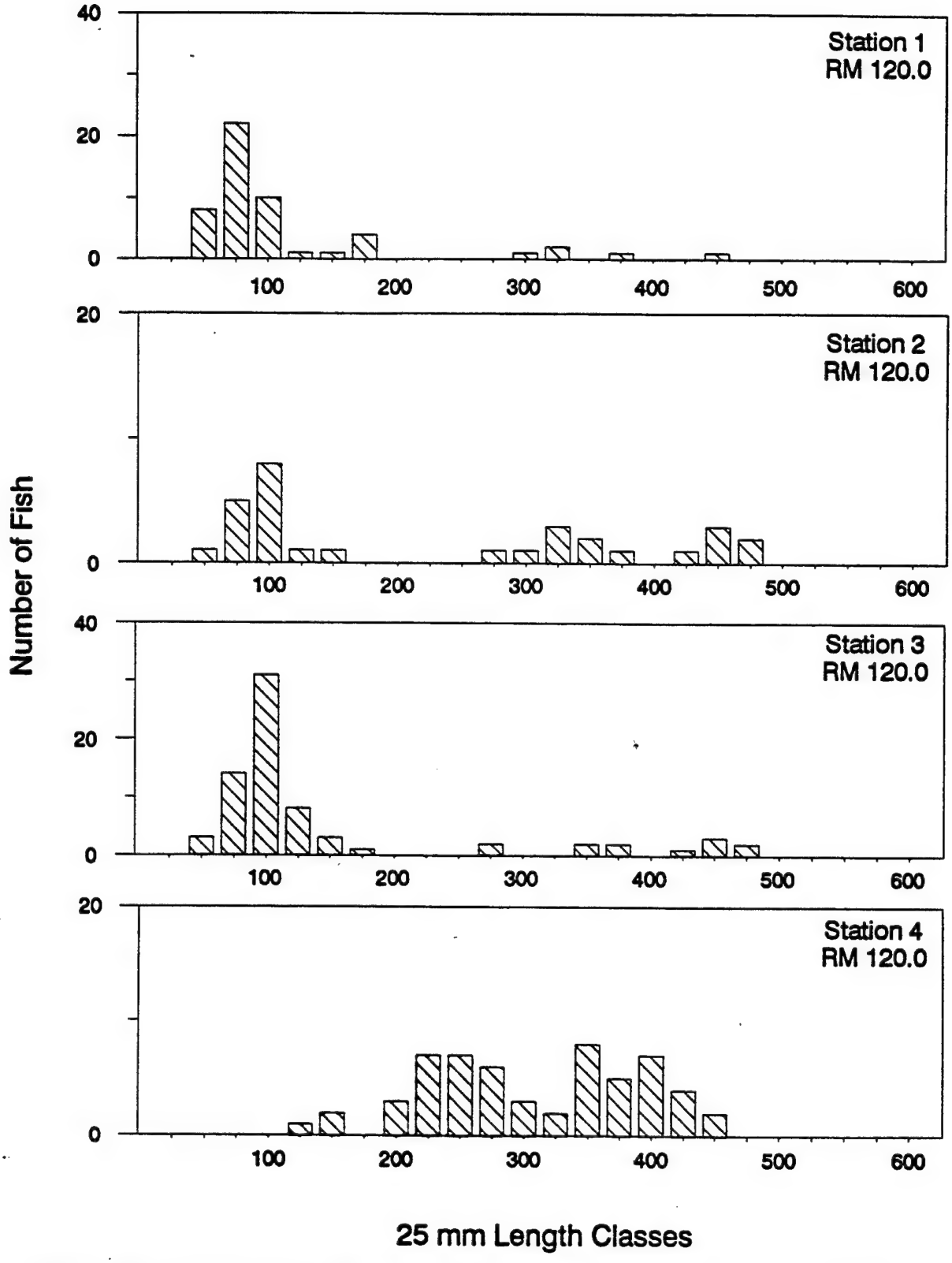


Figure 13. Length distributions of northern squawfish sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

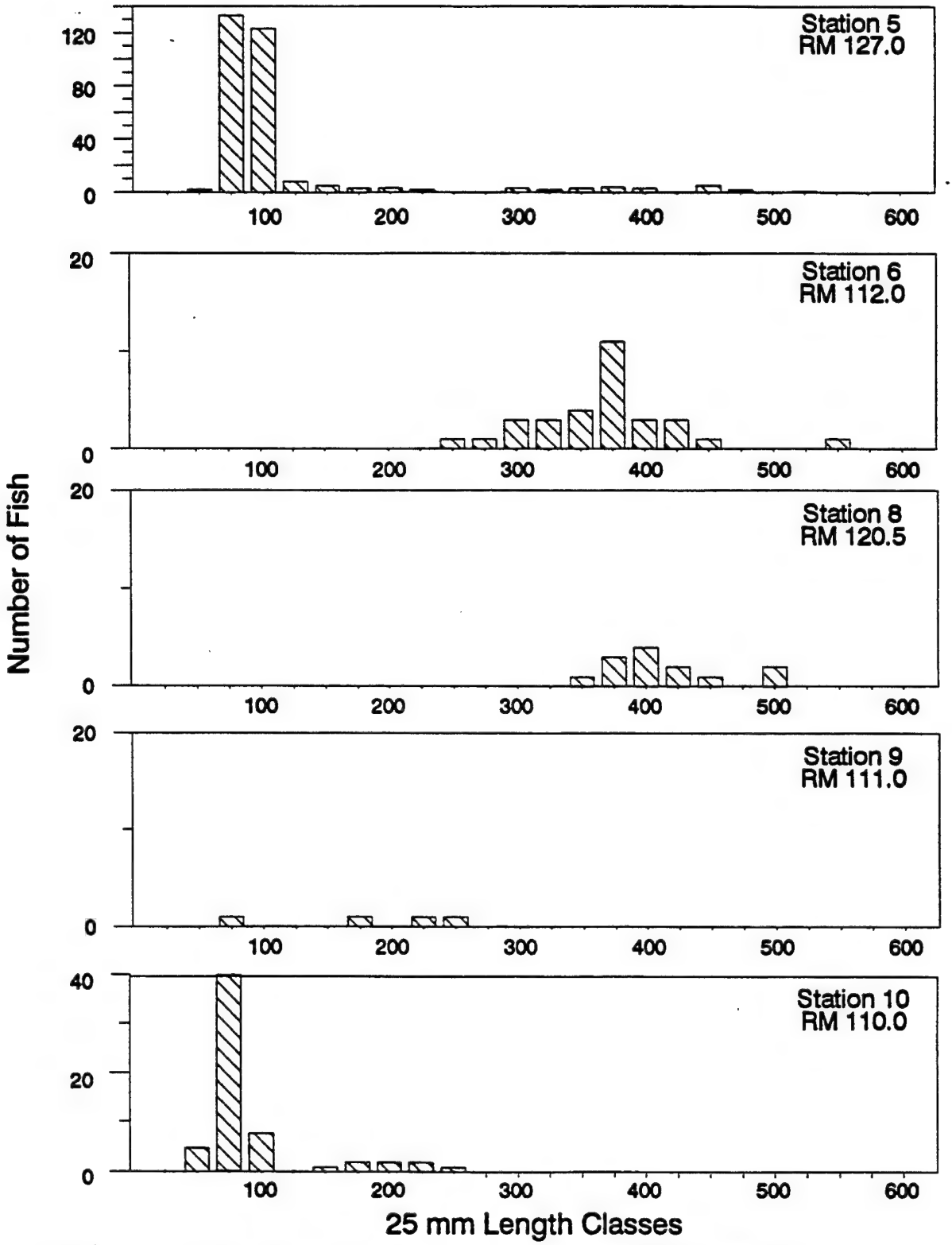


Figure 14. Length distributions of northern squawfish sampled by all gear types at shallow (5, 9 and 10), mid-depth (6) and deep (8) water reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

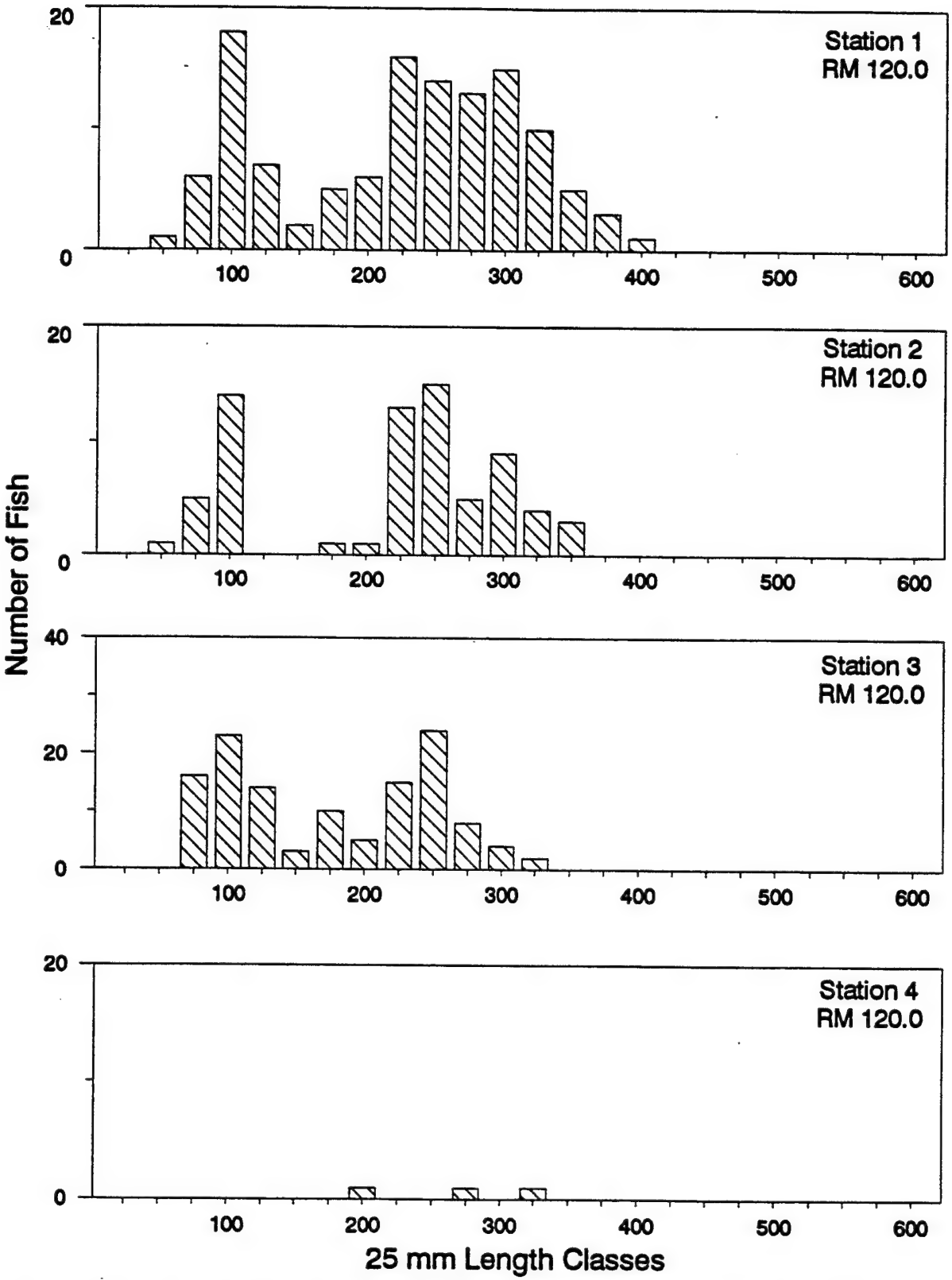


Figure 15. Length distributions of smallmouth bass sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

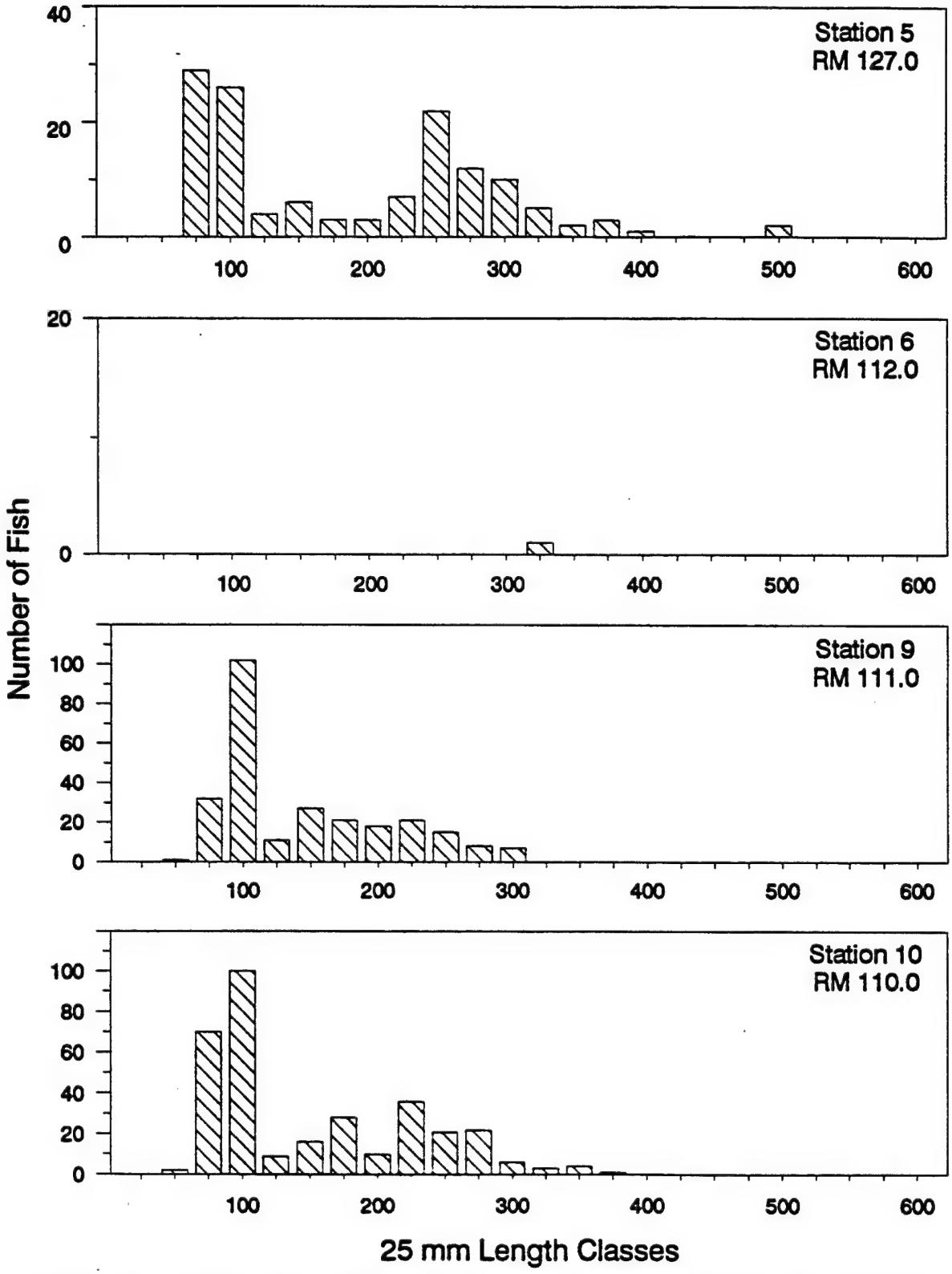


Figure 16. Length distributions of smallmouth bass sampled by all gear types at shallow (5, 9 and 10) and mid-depth (6) reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

station 6. No smallmouth bass were collected at deep water reference station 8 during spring 1991.

Channel catfish.- Few channel catfish were collected during spring 1991 (Figure 17). Most were collected at station 6 and the modal length was 475 mm. However, lengths of catfish ranged from 325-575 mm.

White sturgeon.- Only one white sturgeon was collected, therefore comparisons of lengths are not possible. The sturgeon was sampled at deep water reference station 8 during spring 1991.

Summer

Salmonids.- Only one salmonid was collected during summer 1991, therefore comparisons of lengths are not possible.

Northern squawfish.- Lengths of northern squawfish sampled by electrofishing and beach seining ranged from 50-225 mm (Figure 18). Modal lengths at shallow water disposal station 1 and reference stations 9 and 10 were similar at 125 mm. Low numbers of squawfish were collected at disposal station 2. Those collected at shallow water reference stations 3 and 5 had similar length distributions with modal sizes of 75 mm. Larger northern squawfish were not sampled because gill netting, the principal method of capture, was not employed.

Smallmouth bass.- Length composition of smallmouth bass collected by electrofishing and beach seining during summer ranged from 50-350 mm (Figure 19). Length distributions of smallmouth bass at shallow water disposal and reference stations were similar. The modal length was 50 mm at station 1 and 150 mm at station 2.

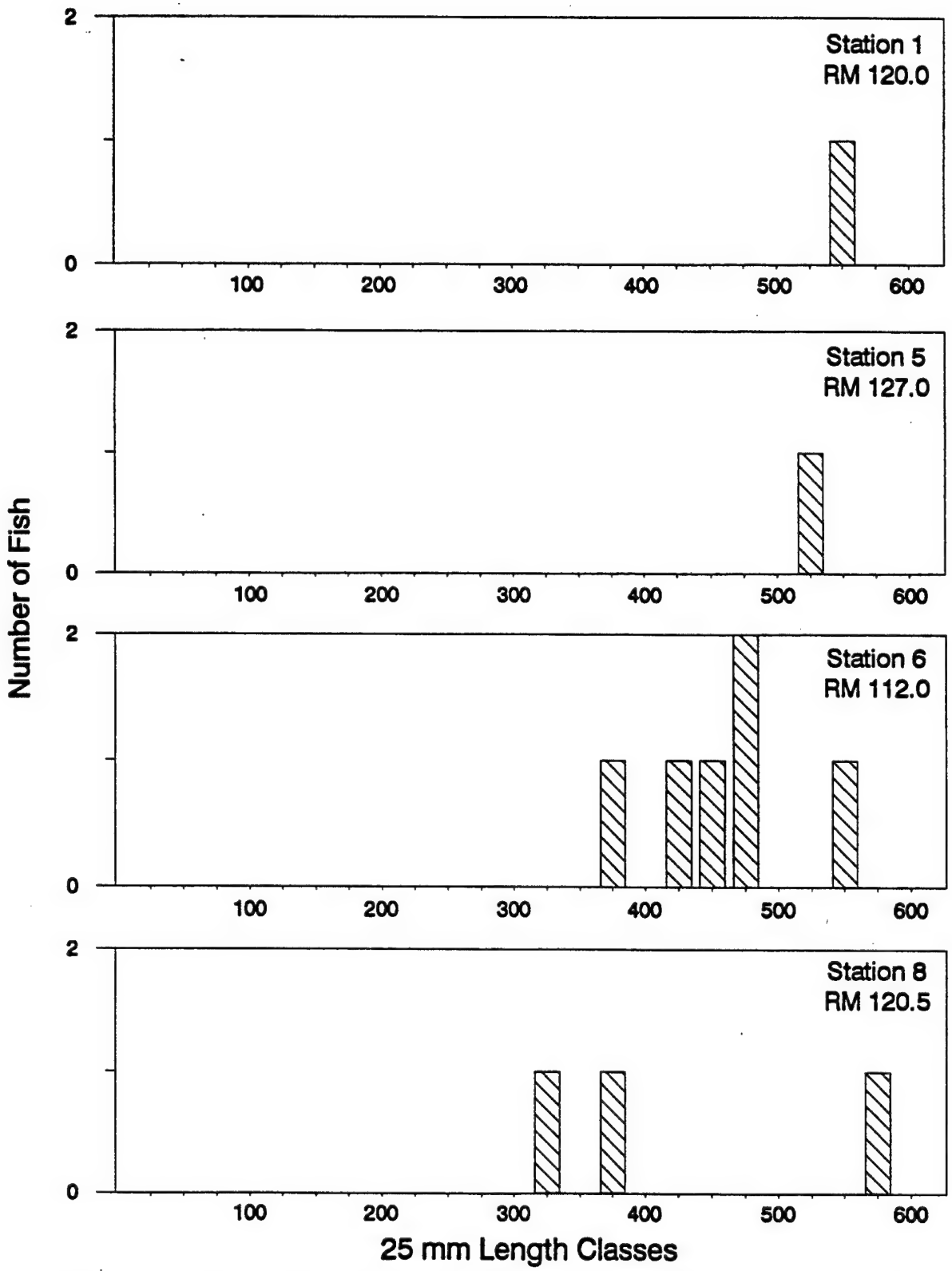


Figure 17. Length distributions of channel catfish sampled by all gear types at shallow water disposal station 1 and shallow (5), mid-depth (6) and deep water (8) reference stations during spring 1991 in Lower Granite Reservoir, Idaho-Washington.

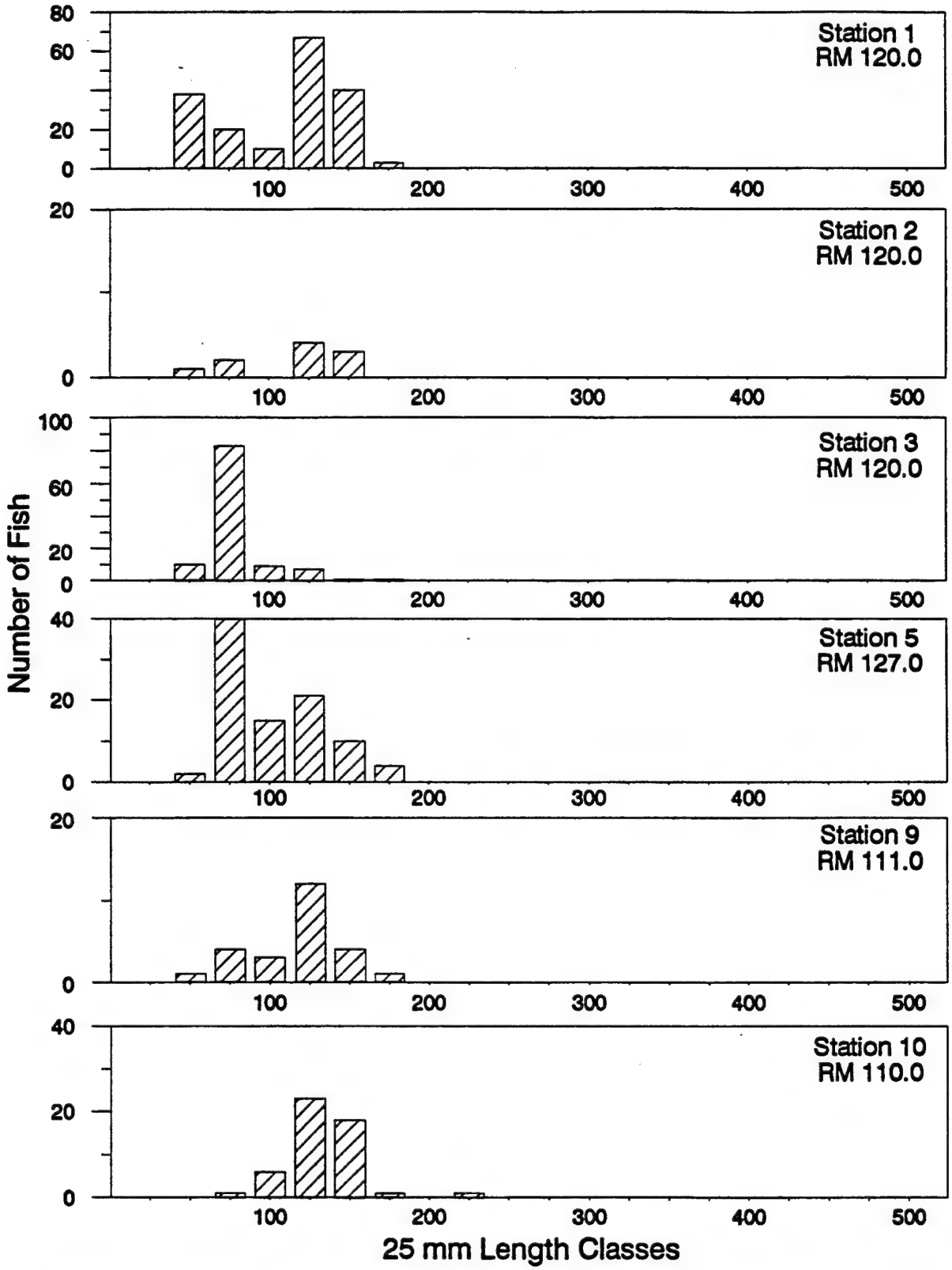


Figure 18. Length distributions of northern squawfish sampled by all gear types at shallow water disposal (1 and 2) and reference (3, 5, 9 and 10) stations during summer 1991 in Lower Granite Reservoir, Idaho-Washington.

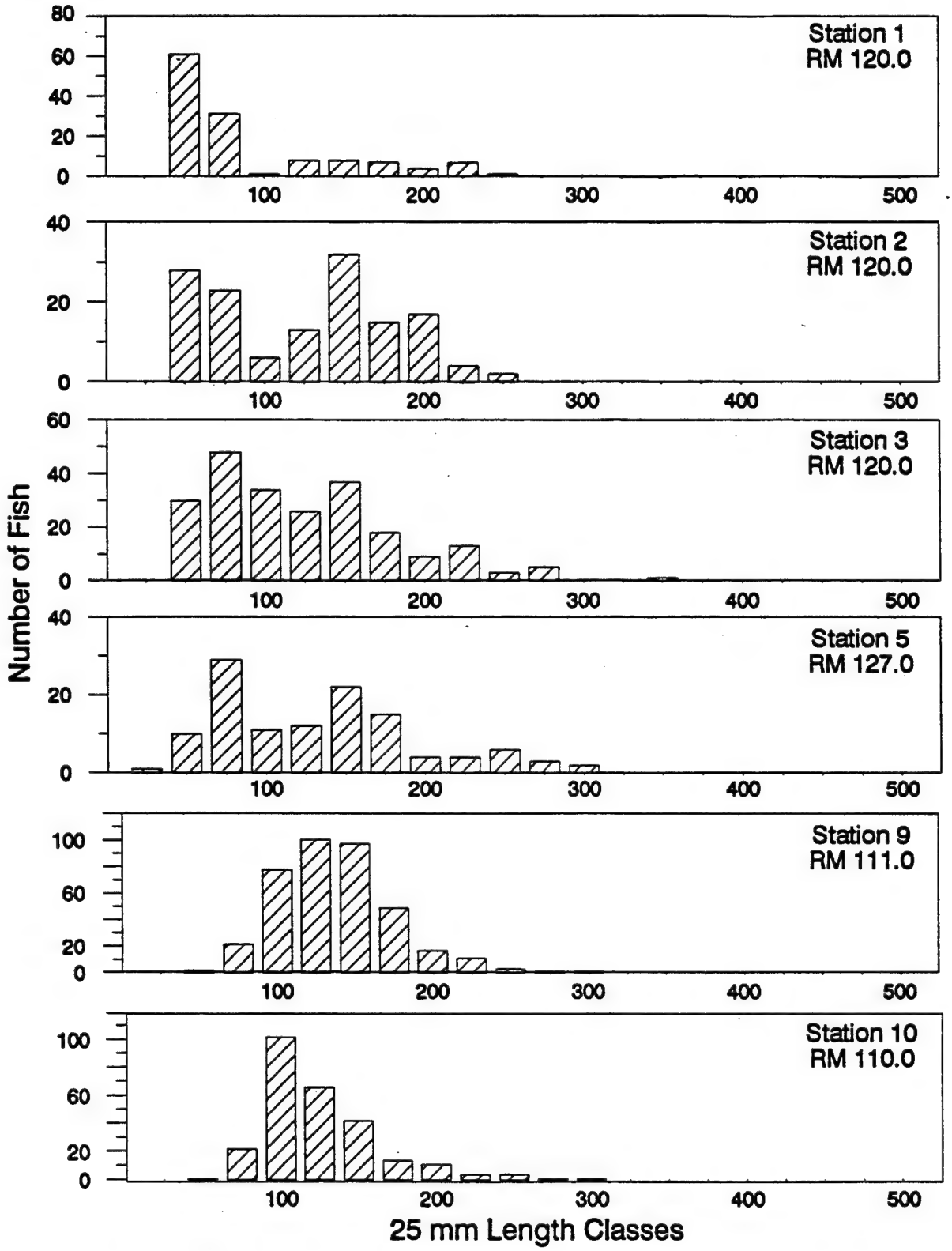


Figure 19. Length distributions of smallmouth bass sampled by all gear types at shallow water disposal (1 and 2) and reference (3, 5, 9 and 10) stations during summer 1991 in Lower Granite Reservoir, Idaho-Washington.

Channel catfish and white sturgeon.- No channel catfish or white sturgeon were sampled during summer 1991. Gill netting was not employed which is the principal method of collection of these species.

Fall

Northern squawfish.- Lengths of northern squawfish sampled during fall by all gear types ranged from 50-500 mm (Figures 20 and 21). The range of lengths reflects the catches of larger squawfish by gill netting. Larger squawfish were generally collected at shallow water disposal station 2 and shallow (5), mid-depth (6) and deep (8) water reference stations. A bimodal distribution of squawfish was present at shallow water reference station 5 (7k mm and 325 mm). Modal lengths at shallow water disposal (1 and 2) and reference (3 and 10) stations were 75 mm.

Smallmouth bass.- Lengths of smallmouth bass collected at shallow water disposal (1 and 2) and reference (3 and 5) stations during fall 1991 were similar (Figure 22 and 23). The modal lengths at these stations were 75 mm. Lengths of smallmouth bass at stations 9 and 10 were bimodal at 75 mm and 150 mm. Disposal stations 1 and 2 suggested bimodal distributions but numbers of fish were low, thus limiting comparisons. Smallmouth bass were collected in low numbers at mid-depth disposal station 4 and reference station 6, so no length comparisons were possible. No bass were collected at deep water reference station 8.

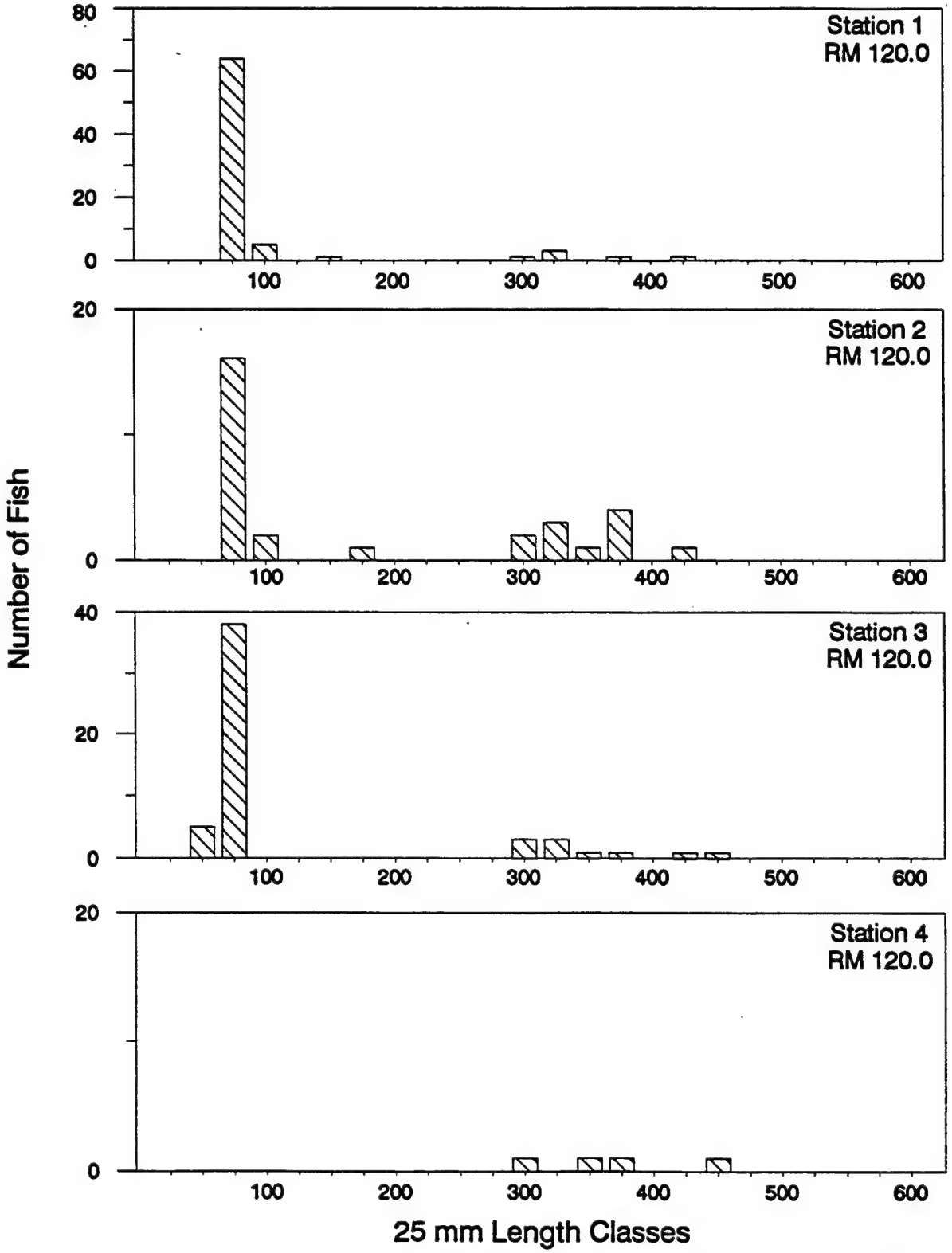


Figure 20. Length distributions of northern squawfish sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

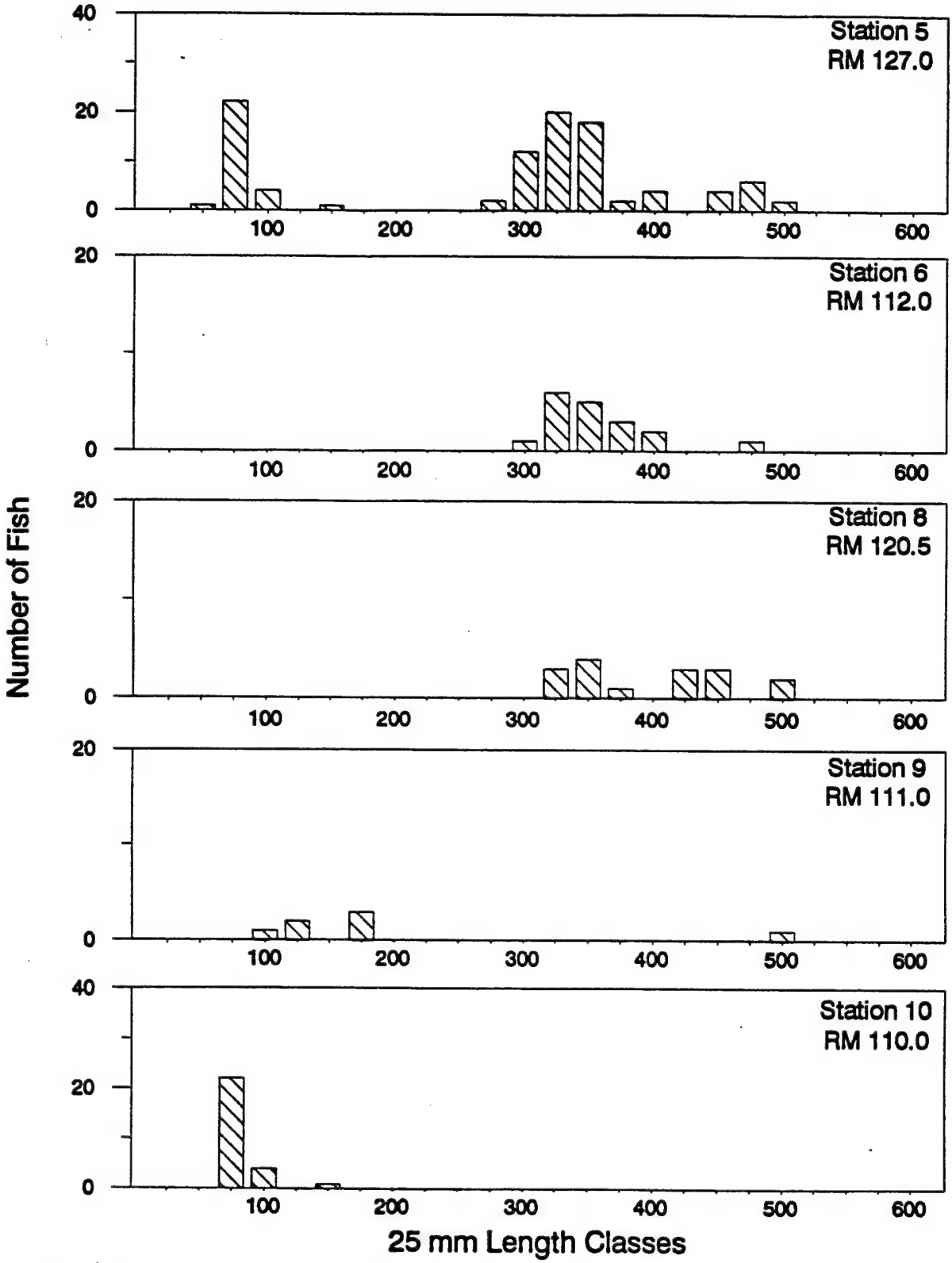


Figure 21. Length distributions of northern squawfish sampled by all gear types at shallow (5, 9 and 10), mid-depth (6) and deep (8) water reference stations during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

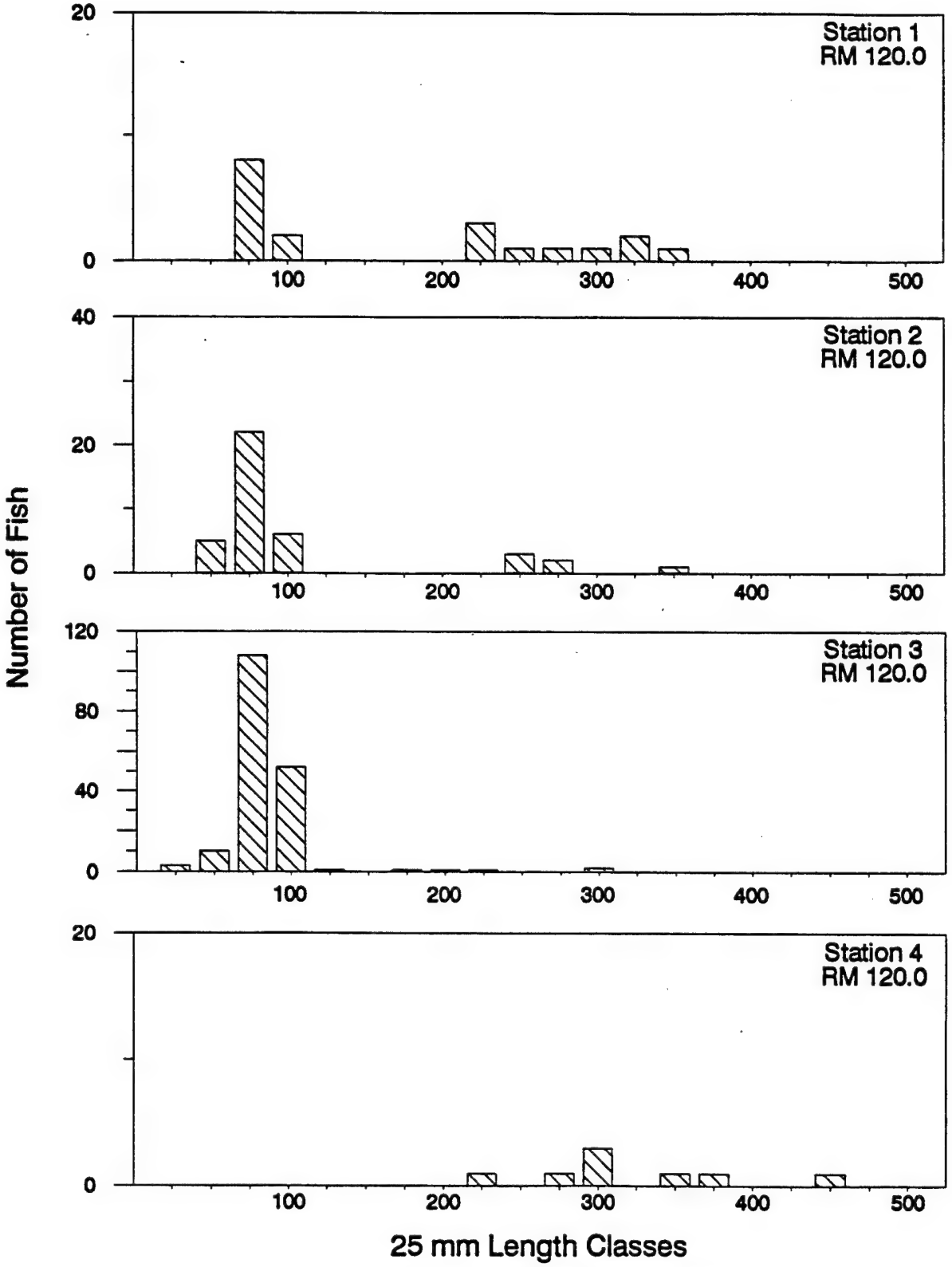


Figure 22. Length distributions of smallmouth bass sampled by all gear types at shallow (1 and 2) and mid-depth (4) disposal stations and shallow water reference station 3 during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

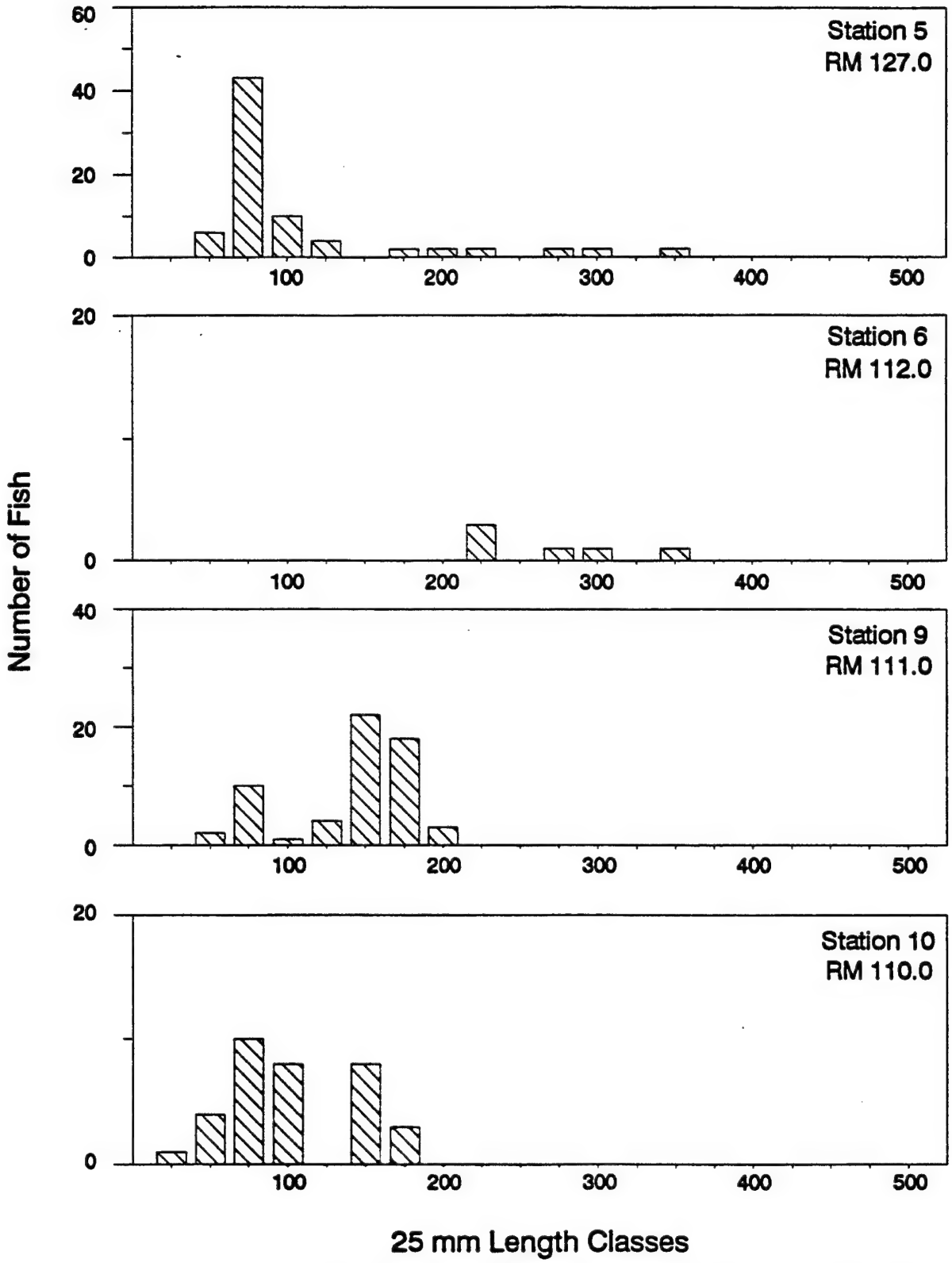


Figure 23. Length distributions of smallmouth bass sampled by all gear types at shallow (5, 9 and 10) and mid-depth (6) reference stations during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

Channel catfish.- All channel catfish collected during fall 1991 ranged in length between 375-500 mm (Figure 24). Numbers sampled during fall were low at all stations.

White sturgeon.- The length composition of white sturgeon collected during fall 1991 ranged from 445-923 mm (Figure 25). White sturgeon were collected at disposal station 2 and reference station 8. Few sturgeon were collected at the regular sampling stations, however seasonal length information is presented under Objective 2.

Abundance by Gear Type

1991

Chinook salmon.- The highest catch/effort of juvenile chinook salmon sampled by beach seining occurred at reference station 5 followed by reference station 3 and disposal station 1 (Figure 26). Differences in catch/effort among these stations were not significant ($P > 0.05$).

The abundance of juvenile chinook salmon based on nighttime electrofishing was highest at reference station 5 followed by disposal station 1 during 1991 (Figure 27). These differences were not significant ($P > 0.05$) as comparisons of catch/effort were similar among stations.

Comparison of catch/effort for juvenile chinook salmon sampled by surface trawling in 1991 indicated that the highest abundance was at reference station 5 followed by reference station 6 and the forebay at

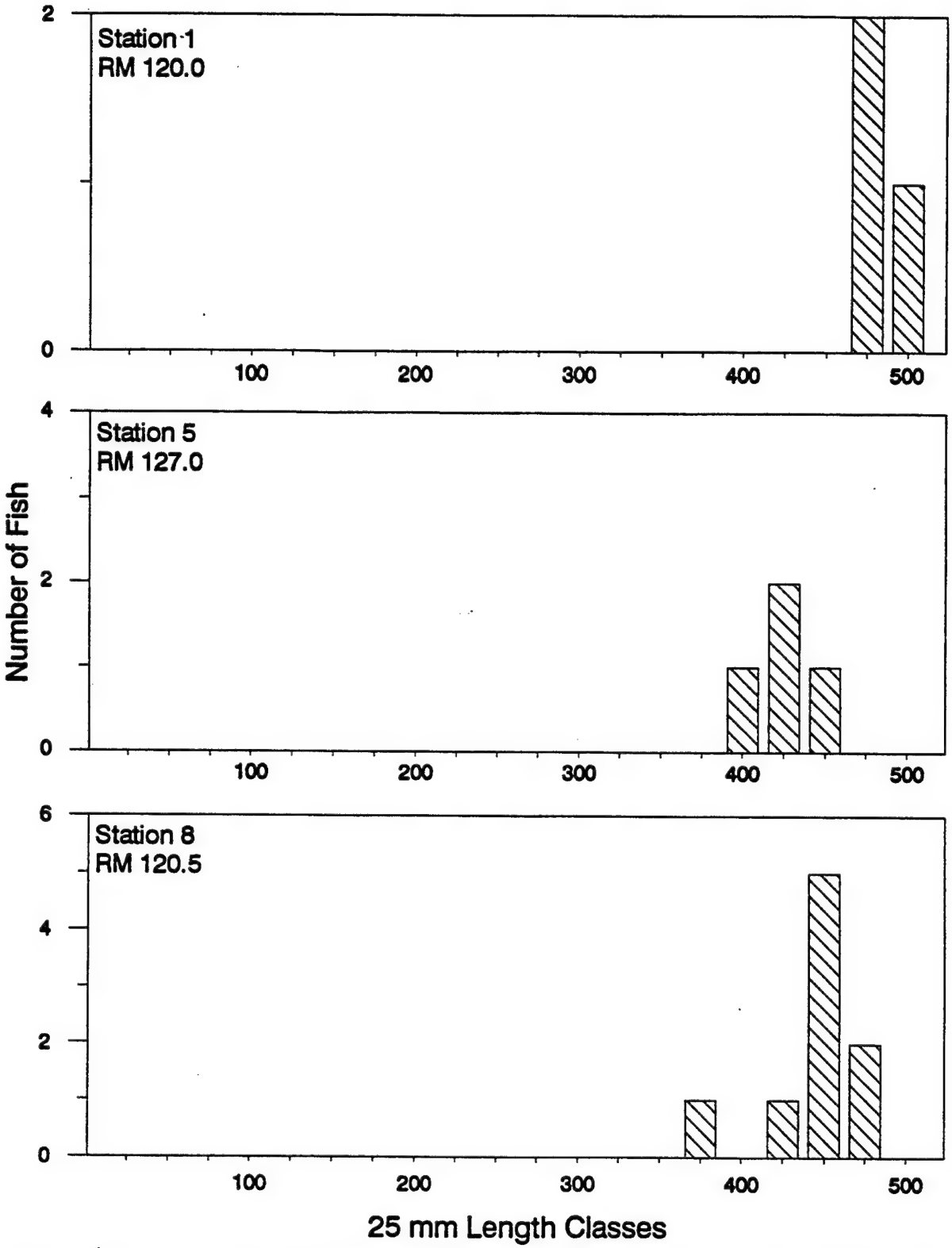


Figure 24. Length distributions of channel catfish sampled by all gear types at shallow water disposal station 1 and shallow (5) and deep (8) water reference stations during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

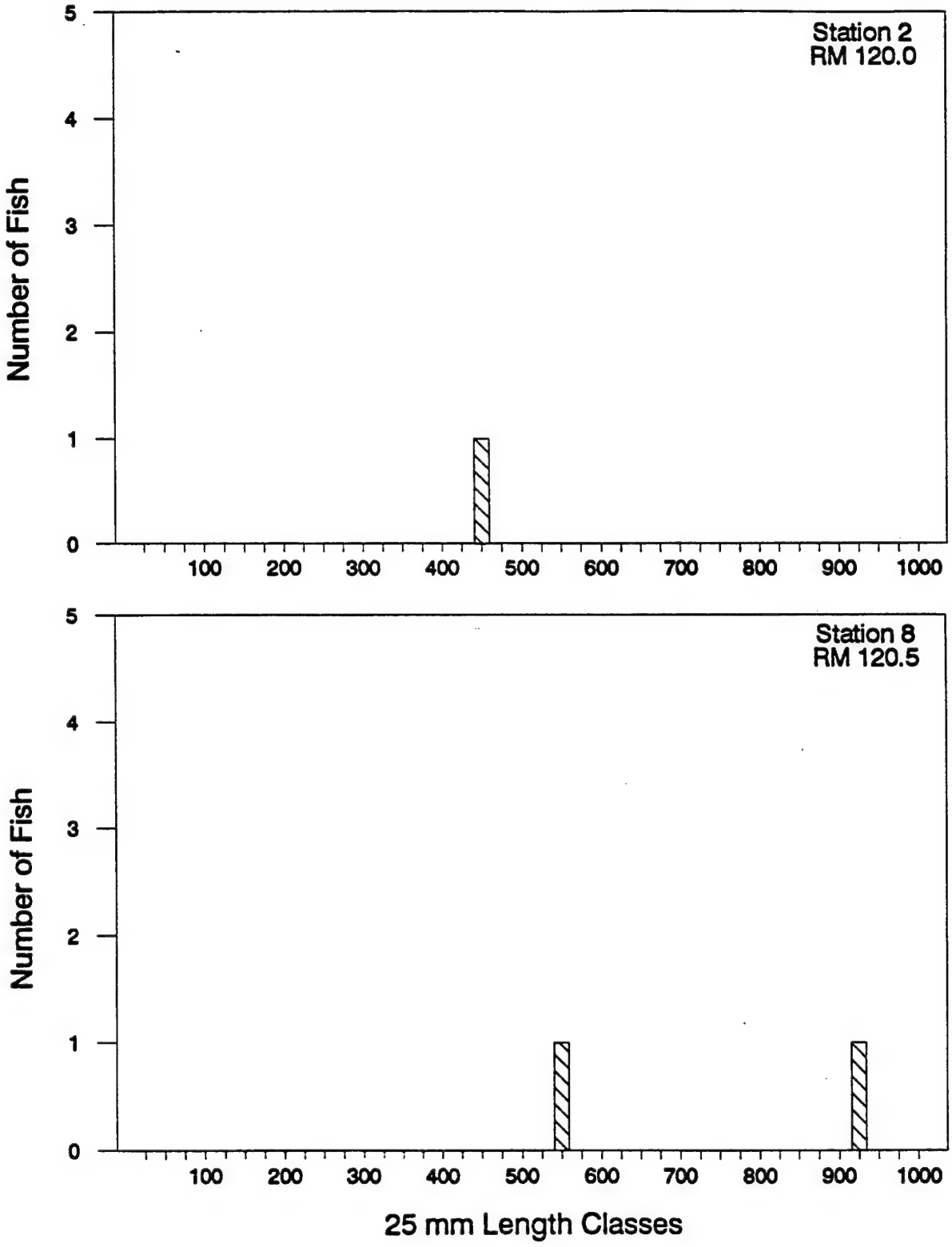


Figure 25. Length distributions of white sturgeon sampled by gill nets and set lines during fall 1991 in Lower Granite Reservoir, Idaho-Washington.

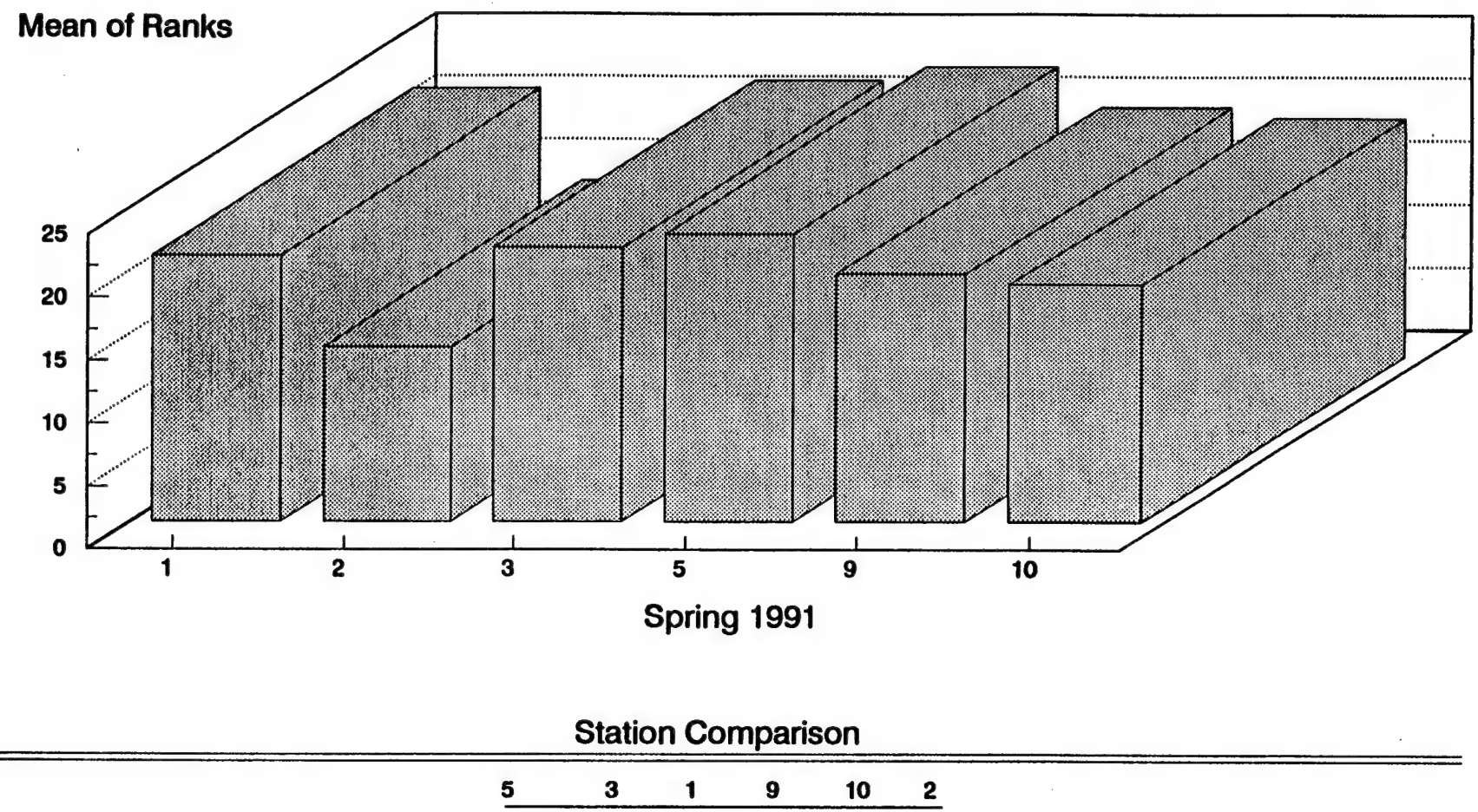
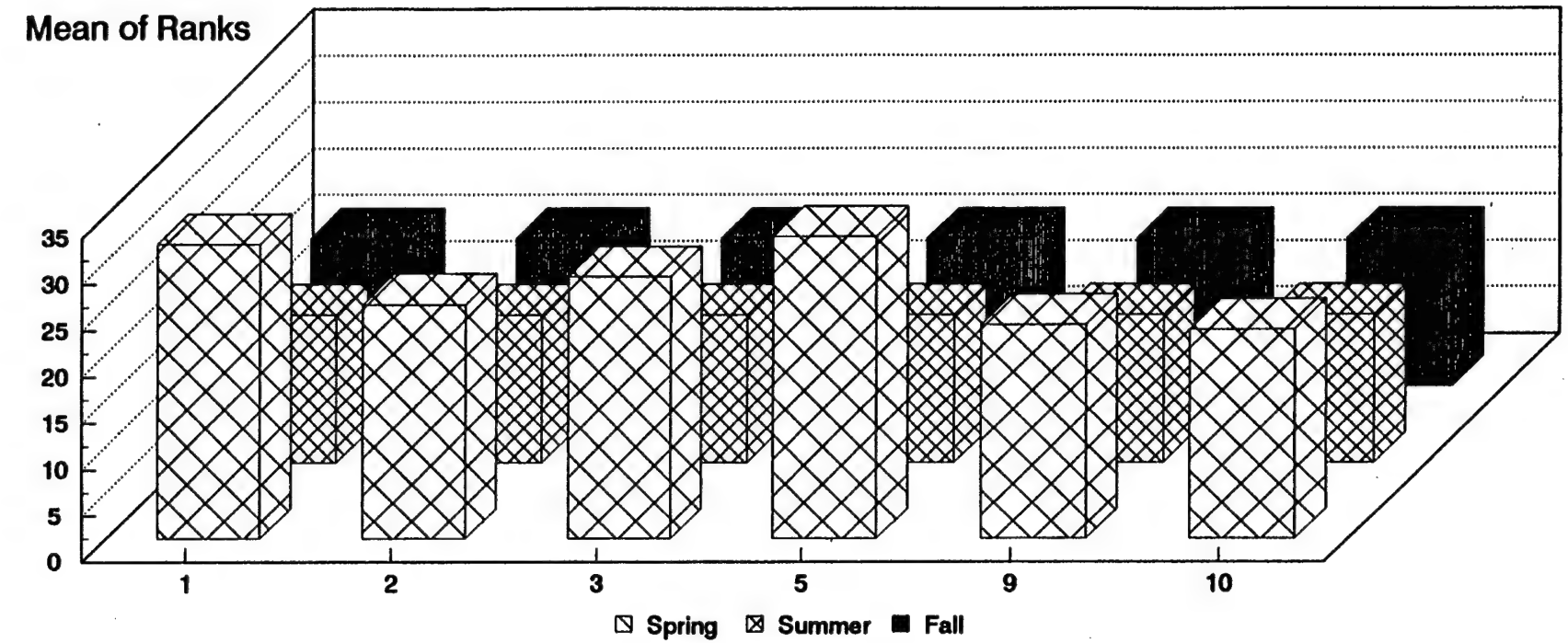


Figure 26. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1991. The horizontal line under stations indicates statistical nonsignificance ($P > 0.05$).



Station Comparison

5 1 3 2 9 10

Season Comparison

Spring Summer Fall

Figure 27. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

RM 108.0 (Figure 28). Differences in catch/effort were significantly ($P < 0.05$) lower at disposal stations 4 and 2.

Steelhead.- The highest catch/effort of juvenile steelhead sampled by beach seining was at reference station 9 and the lowest was at disposal station 2 (Figure 29). Differences in catch/effort among stations were not significant ($P > 0.05$). Seasonal differences in catch/effort were few. Catch/effort by beach seining along the shoreline was significantly higher during spring than summer, but both were not statistically different ($P > 0.05$) from fall.

The highest catch/effort of juvenile steelhead sampled by electrofishing occurred at reference station 9 and the lowest was at disposal station 1 (Figure 30). Differences in catch/effort among stations were not significant ($P > 0.05$).

Seasonal differences in catch/effort of juvenile steelhead sampled by electrofishing were few (Figure 30). Catch/effort was significantly ($P < 0.05$) higher during spring than summer, however differences between spring and fall, and fall and summer were not significant ($P > 0.05$).

Comparisons of catch/effort for juvenile steelhead sampled by surface trawling during 1991 indicated abundance was highest in the forebay followed by reference station 5 (Figure 31). Catch/effort was lowest at disposal station 4, although no statistical differences were found among the five stations sampled.

Northern Squawfish.- No seasonal and few station differences in comparisons of catch/effort were found for northern squawfish sampled by gill netting during 1991 (Figure 32). The highest abundance of northern

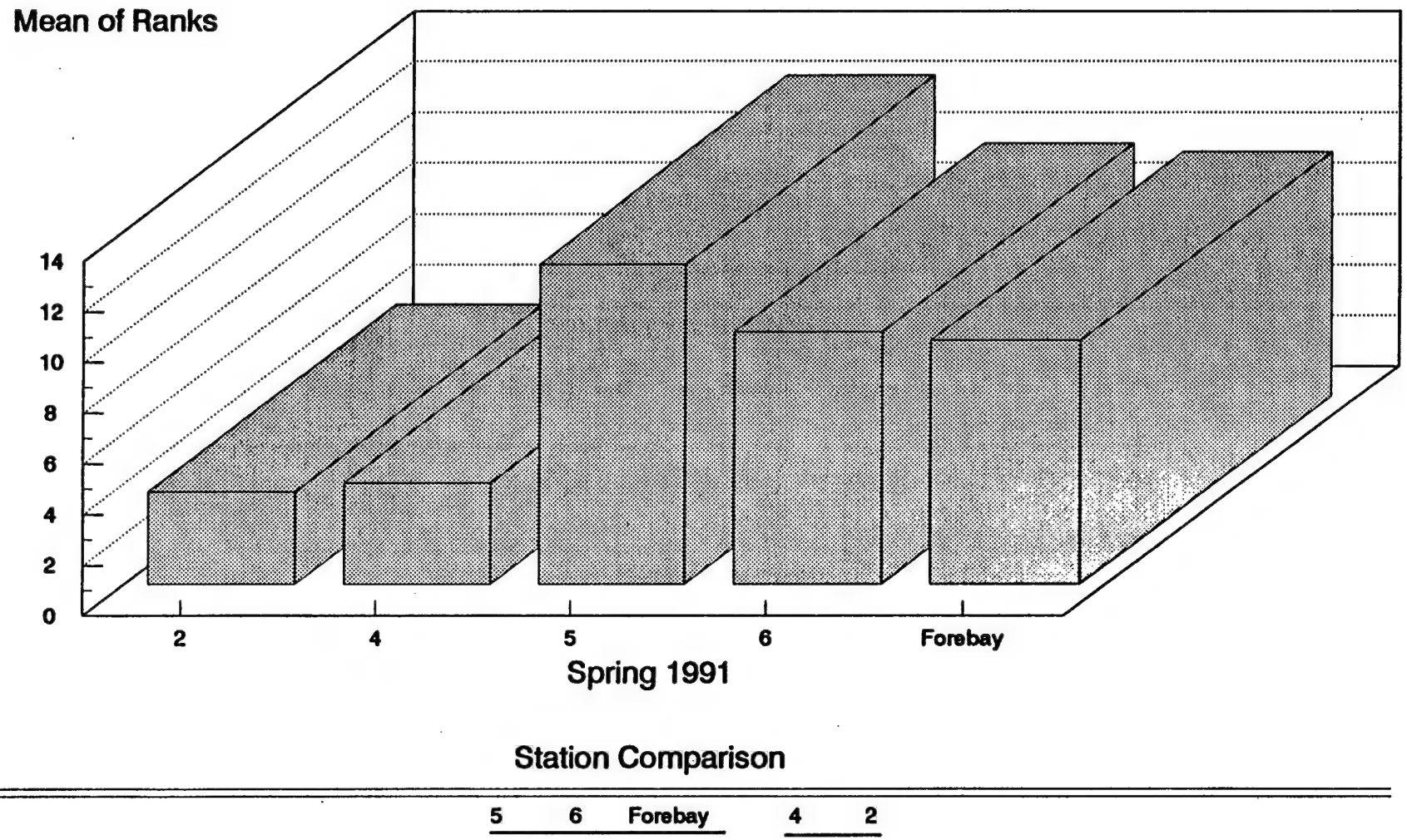


Figure 28. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by surface trawling in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations indicate statistical nonsignificance ($P > 0.05$).

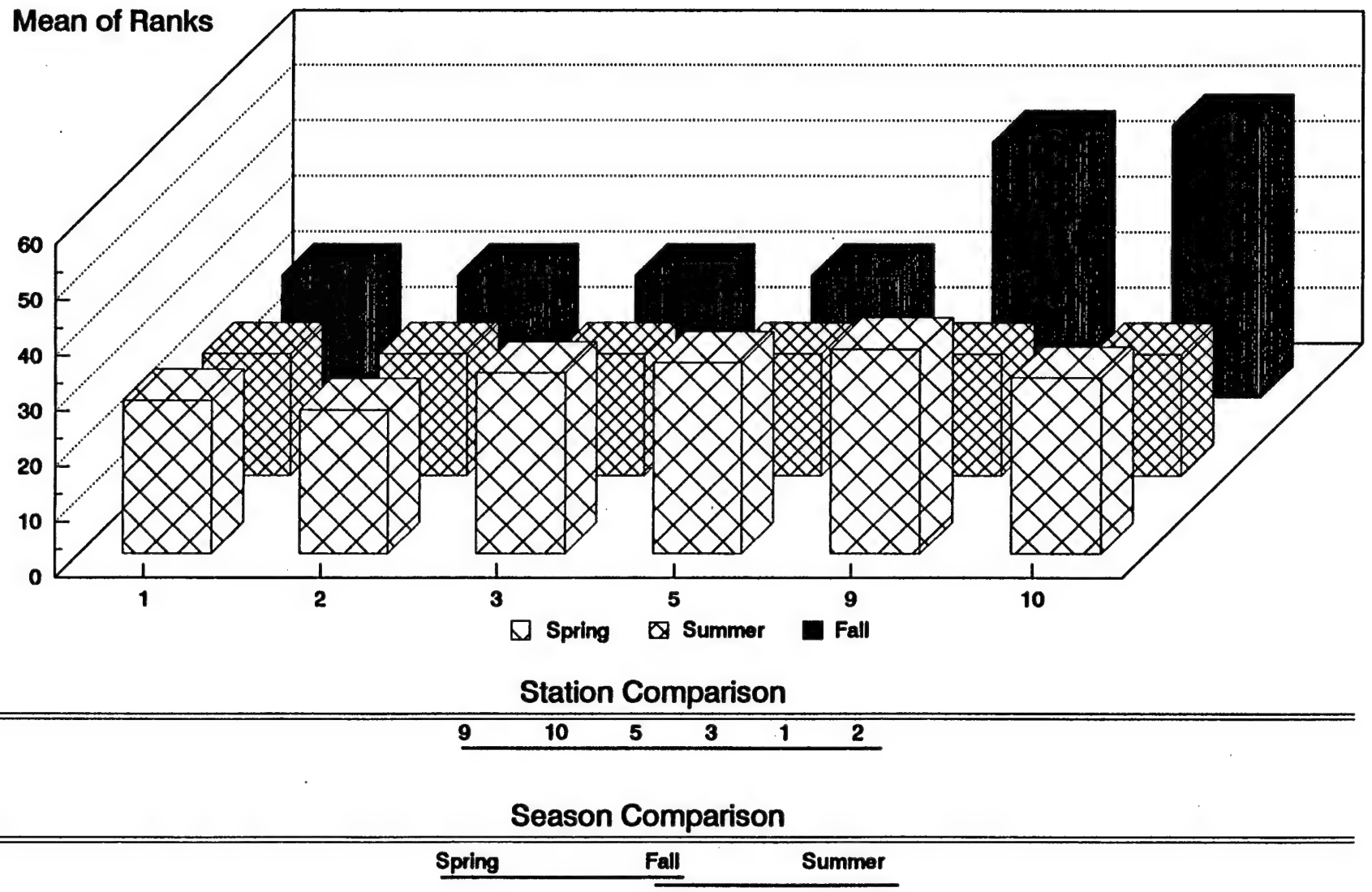


Figure 29. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance (P > 0.05).

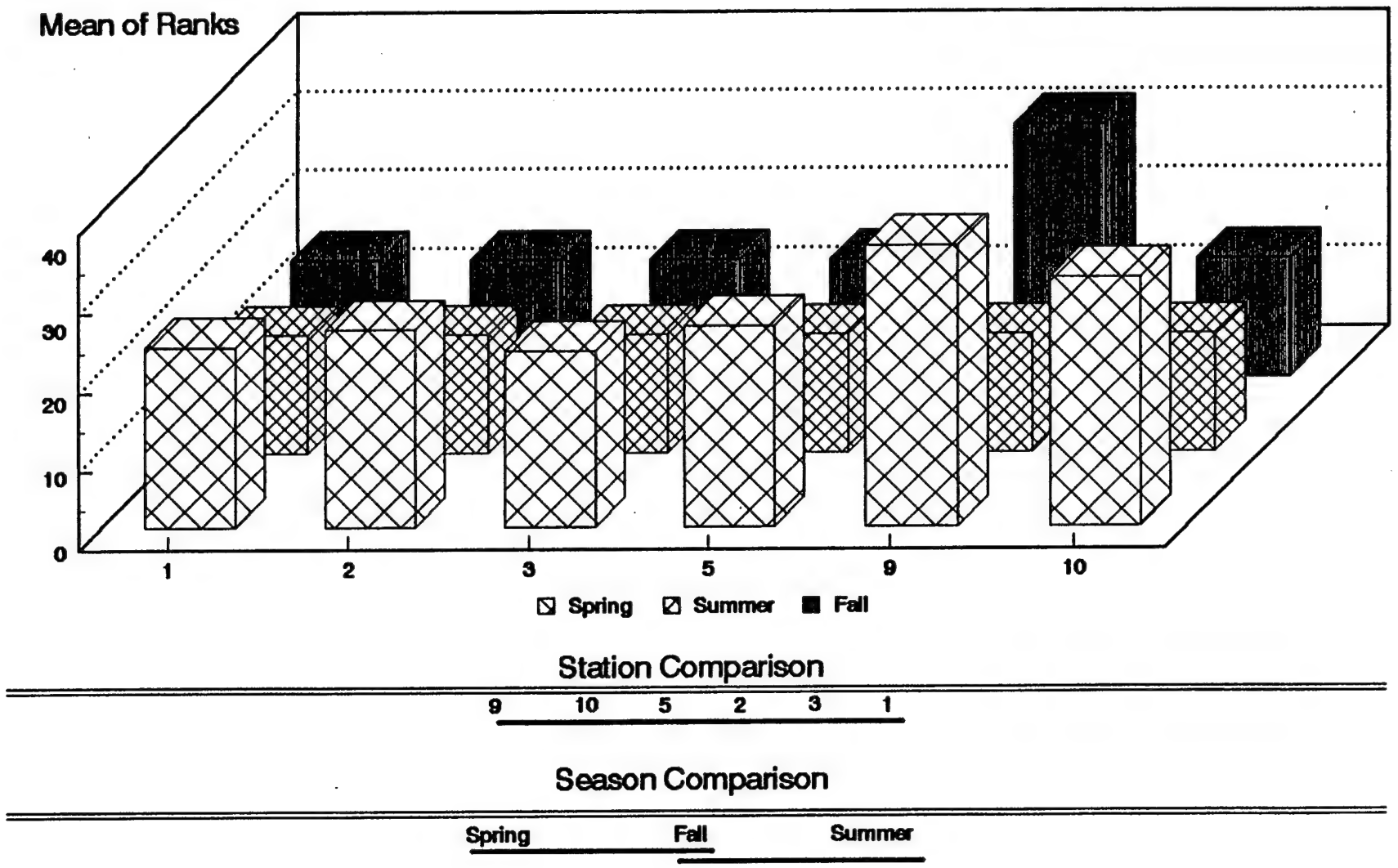


Figure 30. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

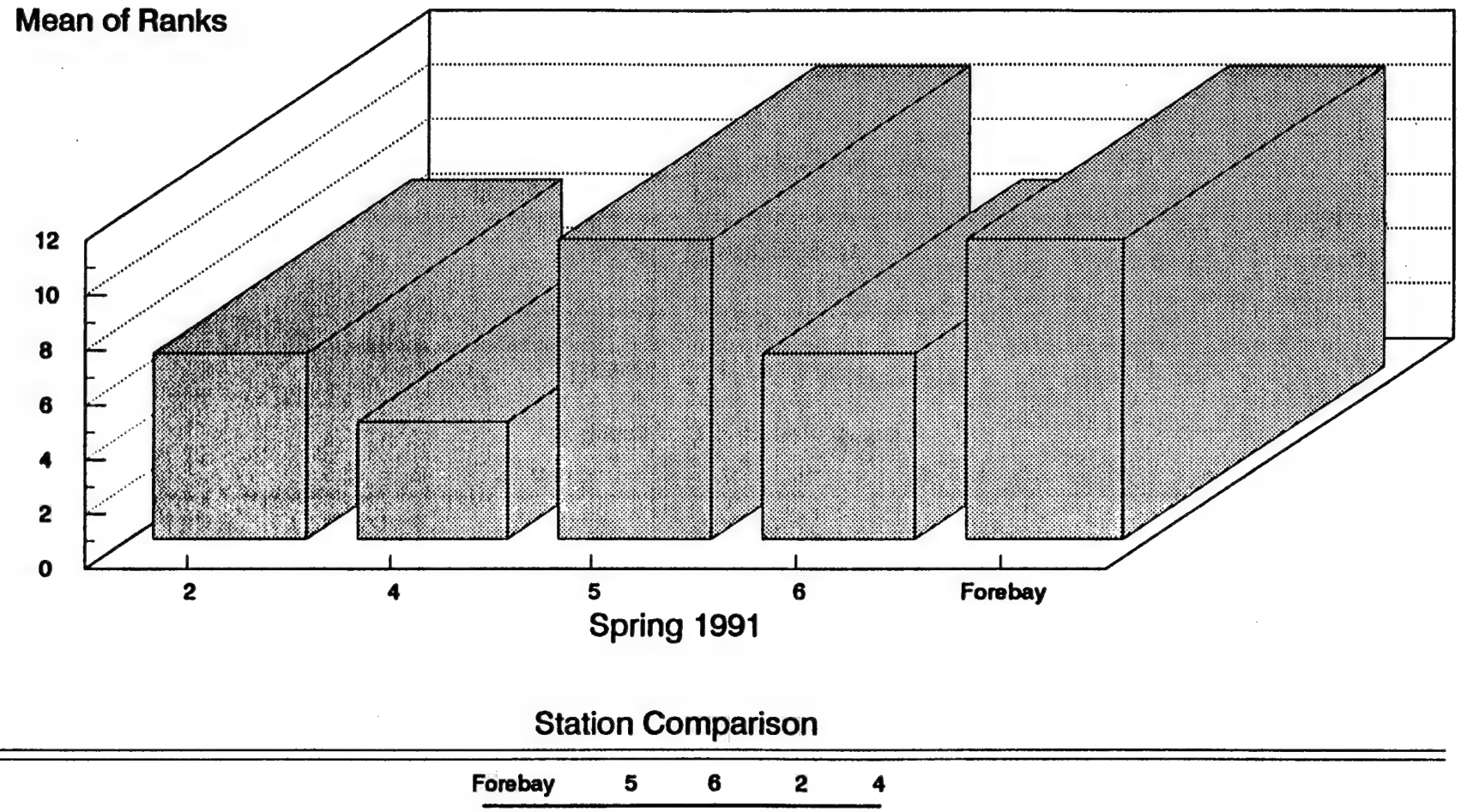


Figure 31. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by surface trawling in Lower Granite Reservoir, Idaho-Washington during 1991. The horizontal line under stations indicates statistical nonsignificance ($P > 0.05$).

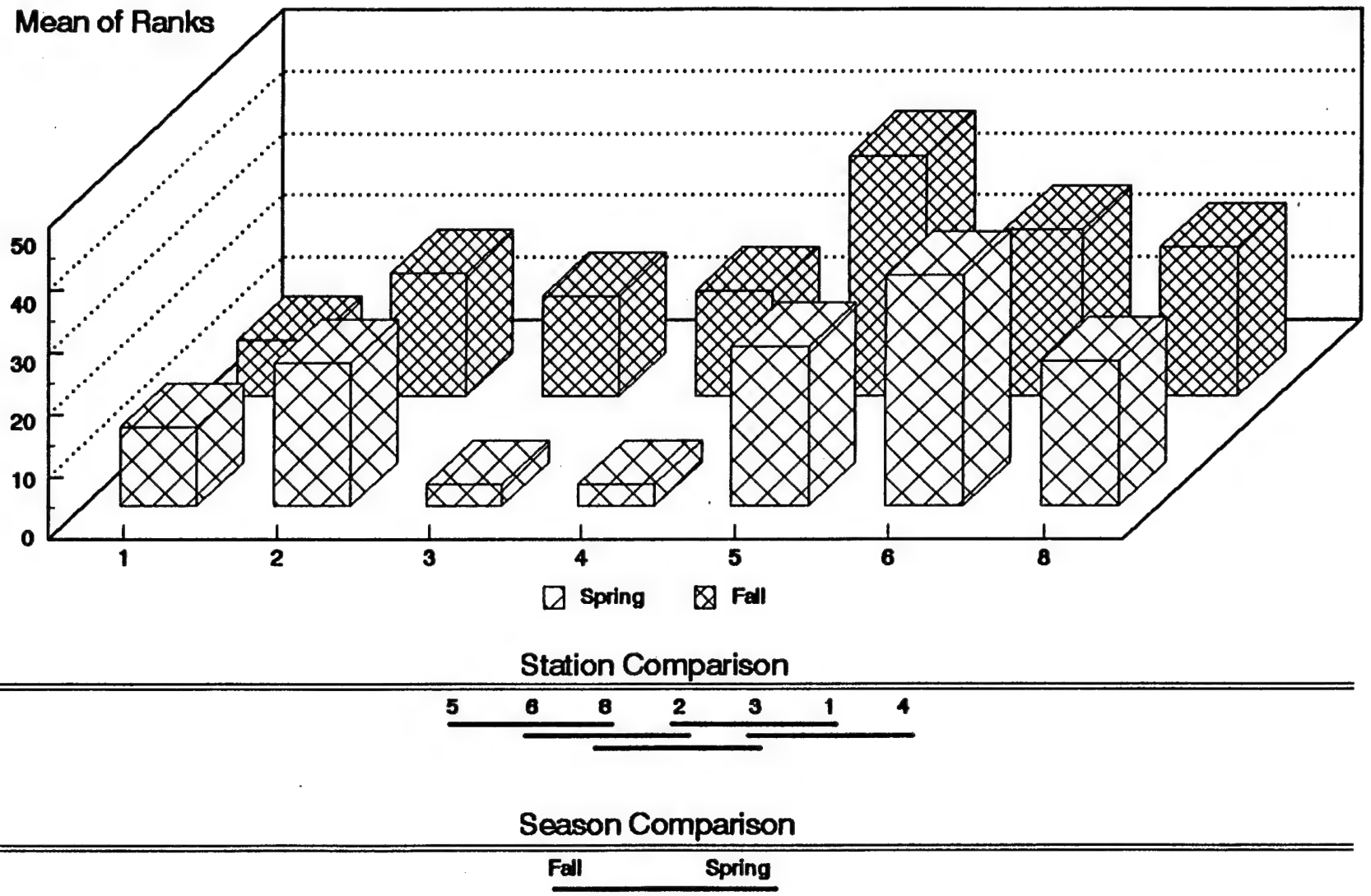


Figure 32. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

squawfish occurred at reference stations 5, 6 and 8 followed by disposal stations 2, 1 and 4. Differences in catch/effort were significant ($P < 0.05$) between reference station 5 and all the disposal stations. Seasonal differences in catch/effort were not significant ($P > 0.05$) from fall to spring.

The highest abundance of northern squawfish based on comparisons of catch/effort by beach seining occurred at reference stations 10 and 5 (Figure 33). The lowest abundance was at reference station 9. Comparisons of catch/effort were statistically ($P < 0.05$) different between the high at reference station 10 and the low at reference station 9. Seasonal differences were not found in 1991 as catch/effort was statistically similar among fall, spring and summer (Figure 33).

Comparisons of catch/effort of northern squawfish sampled by nighttime electrofishing during 1991 varied spatially and temporally (Figure 34). Differences in catch/effort indicated the highest abundance was at reference station 5 followed by reference station 3 and disposal station 1. None of these differences in catch/effort were significant ($P > 0.05$), although catch/effort at these stations was significantly ($P < 0.05$) higher than those at other reference and disposal stations.

The highest catch/effort of northern squawfish sampled by nighttime electrofishing occurred during fall and was followed by summer and spring (Figure 34). Differences in catch/effort were significant ($P < 0.05$) from fall to spring, but catches were not different between fall and summer.

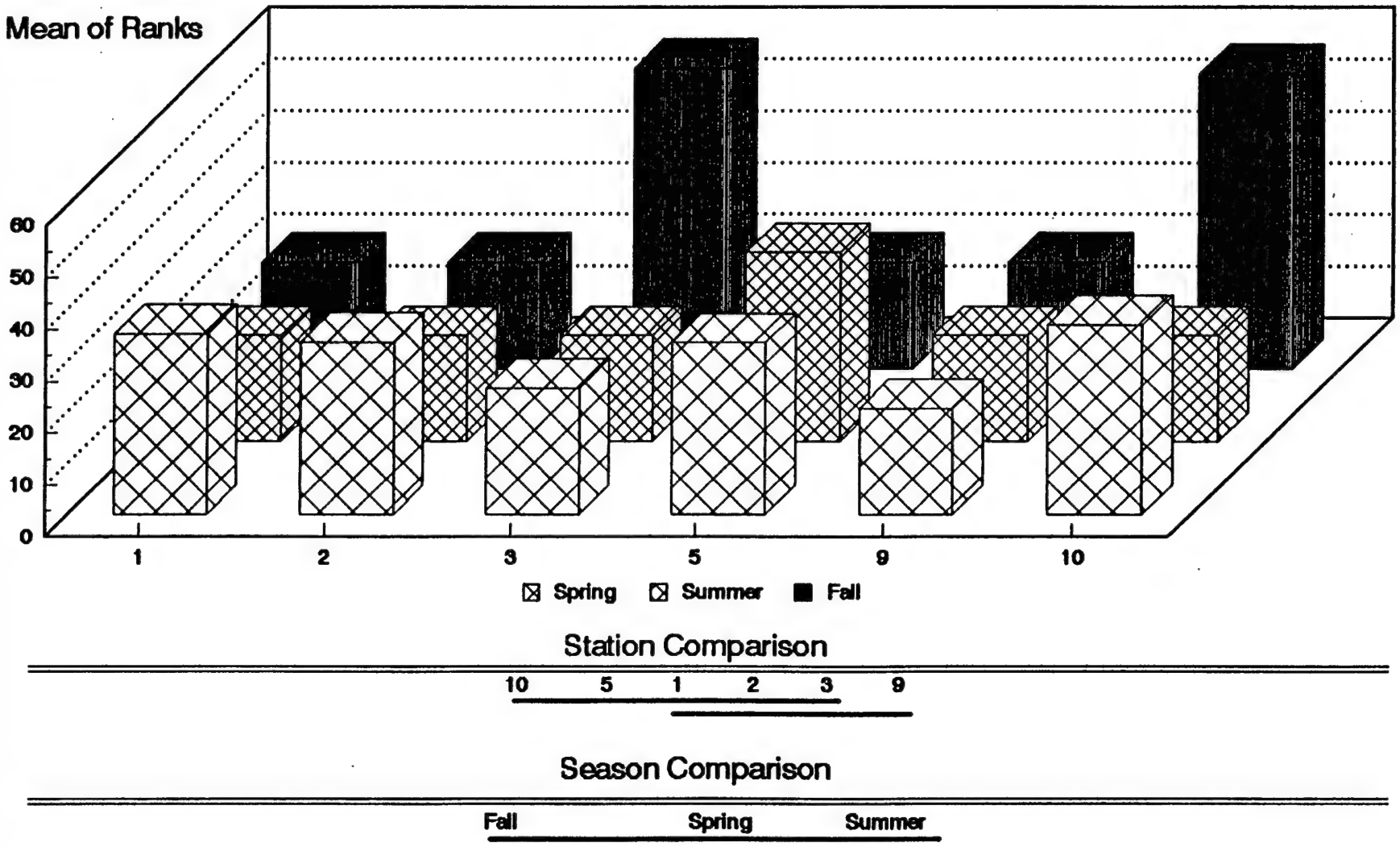


Figure 33. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

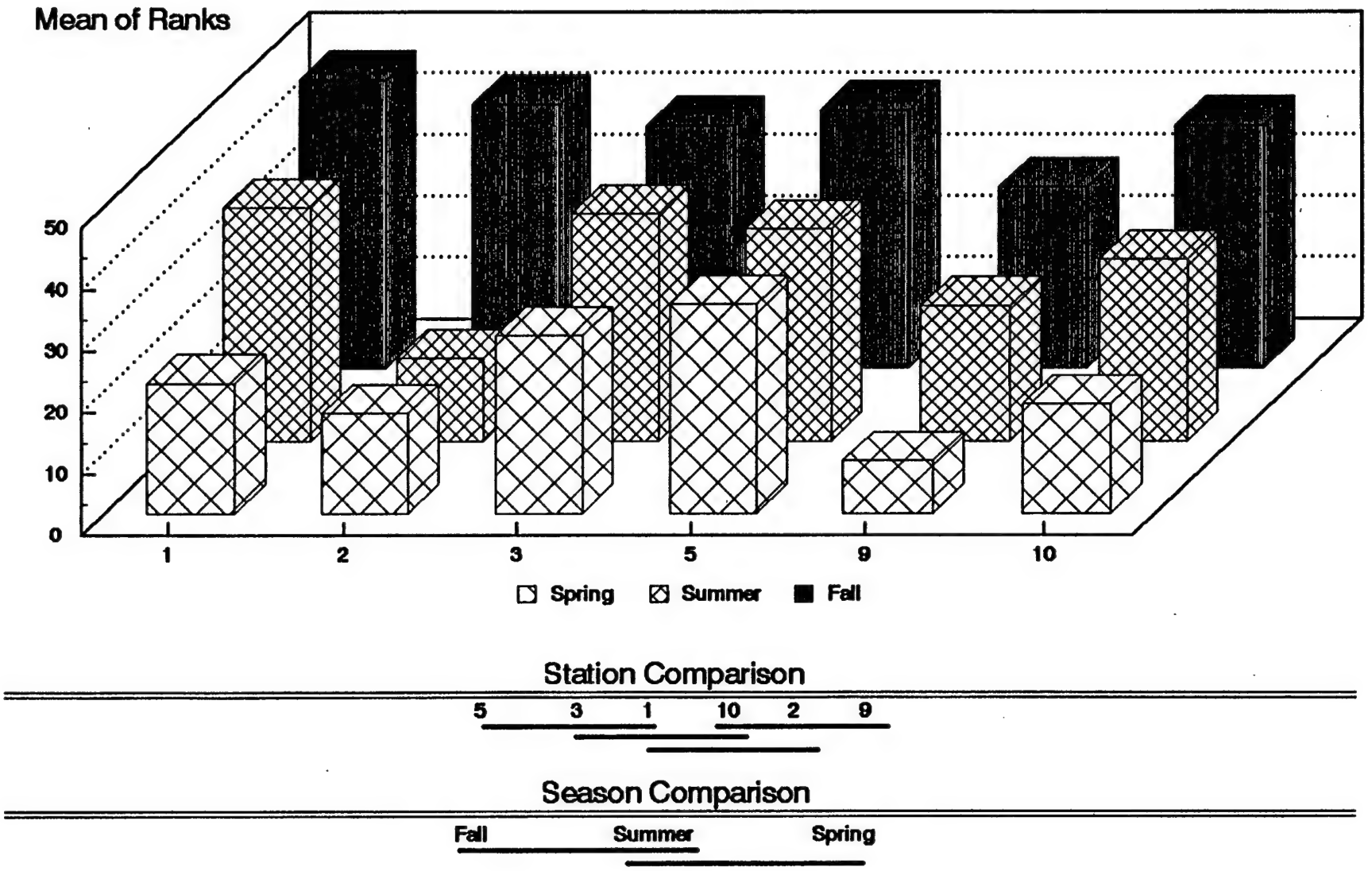


Figure 34. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

Smallmouth bass.- Few station differences in catch/effort of smallmouth bass sampled by gill netting were found during 1991 (Figure 35). The highest catch/effort occurred at reference station 3 and was followed by those at disposal station 2. The lowest catch/effort for smallmouth bass was at deep water reference station 8. Catch rates of smallmouth bass at all shallow and mid-depth stations were significantly higher than those at reference station 8.

The highest catch/effort of smallmouth bass by gill netting was during fall, however, comparisons between fall and spring were not statistically ($P > 0.05$) significant (Figure 35).

The abundance of smallmouth bass by daytime beach seining indicated temporal and spatial differences (Figure 36). The highest catch/effort of smallmouth bass occurred at reference station 10 followed by disposal station 1. Reference station 5 had the lowest catch/effort. Differences in catch/effort among stations indicated two clusters of abundance. For example, catch/effort was not significantly different among stations 10, 1 and 9, however abundance among these stations was significantly ($P < 0.05$) higher than stations 3, 2 and 5.

The highest catch/effort of smallmouth bass based on beach seining occurred during summer followed by fall and spring (Figure 36). Comparisons between summer and fall were not statistically different but they were both significantly ($P < 0.05$) higher than spring.

The highest catch/effort of smallmouth bass sampled by nighttime electrofishing occurred at reference stations 9, 10 and 3, while disposal station 1 had the lowest (Figure 37). The only significant (P

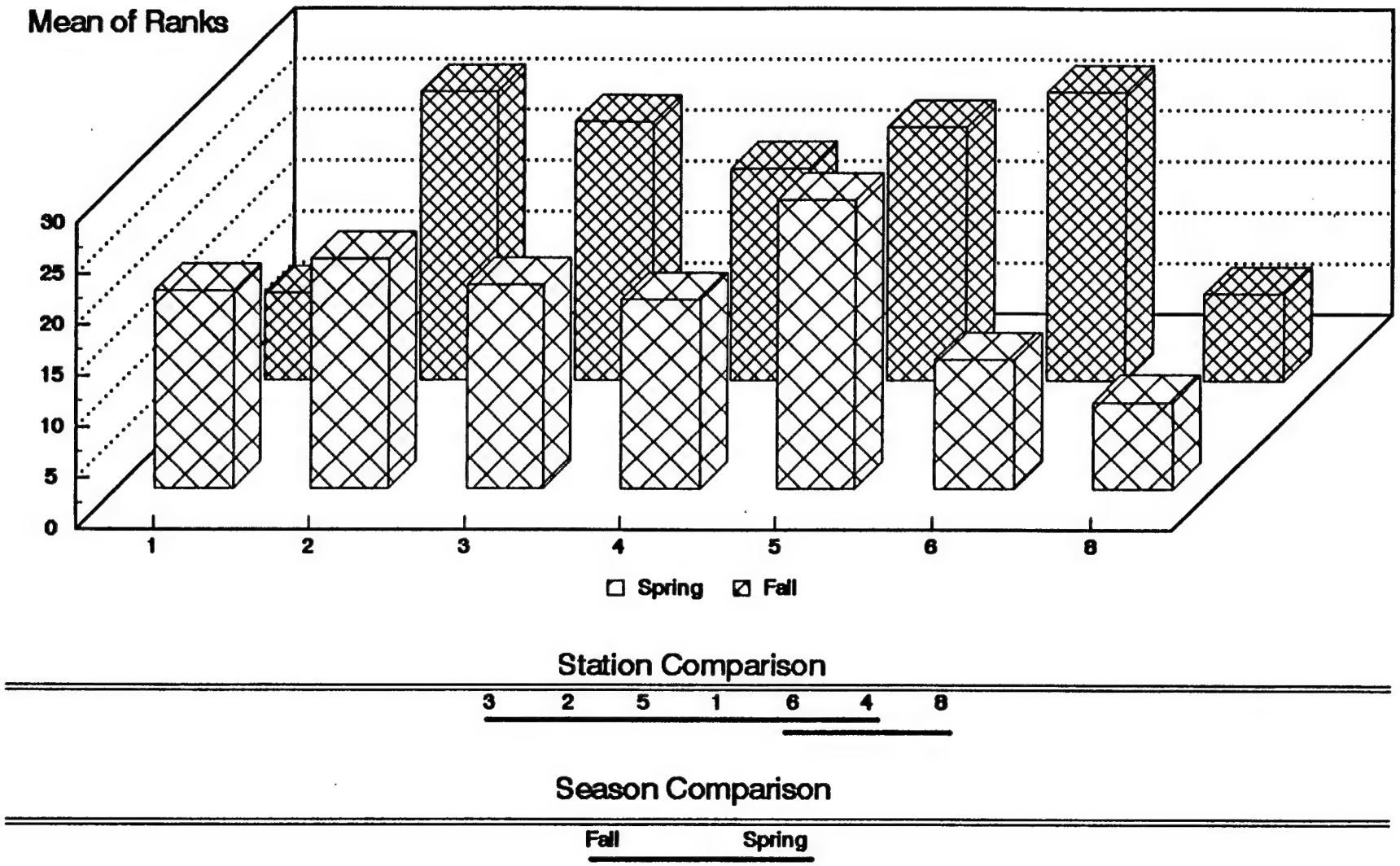
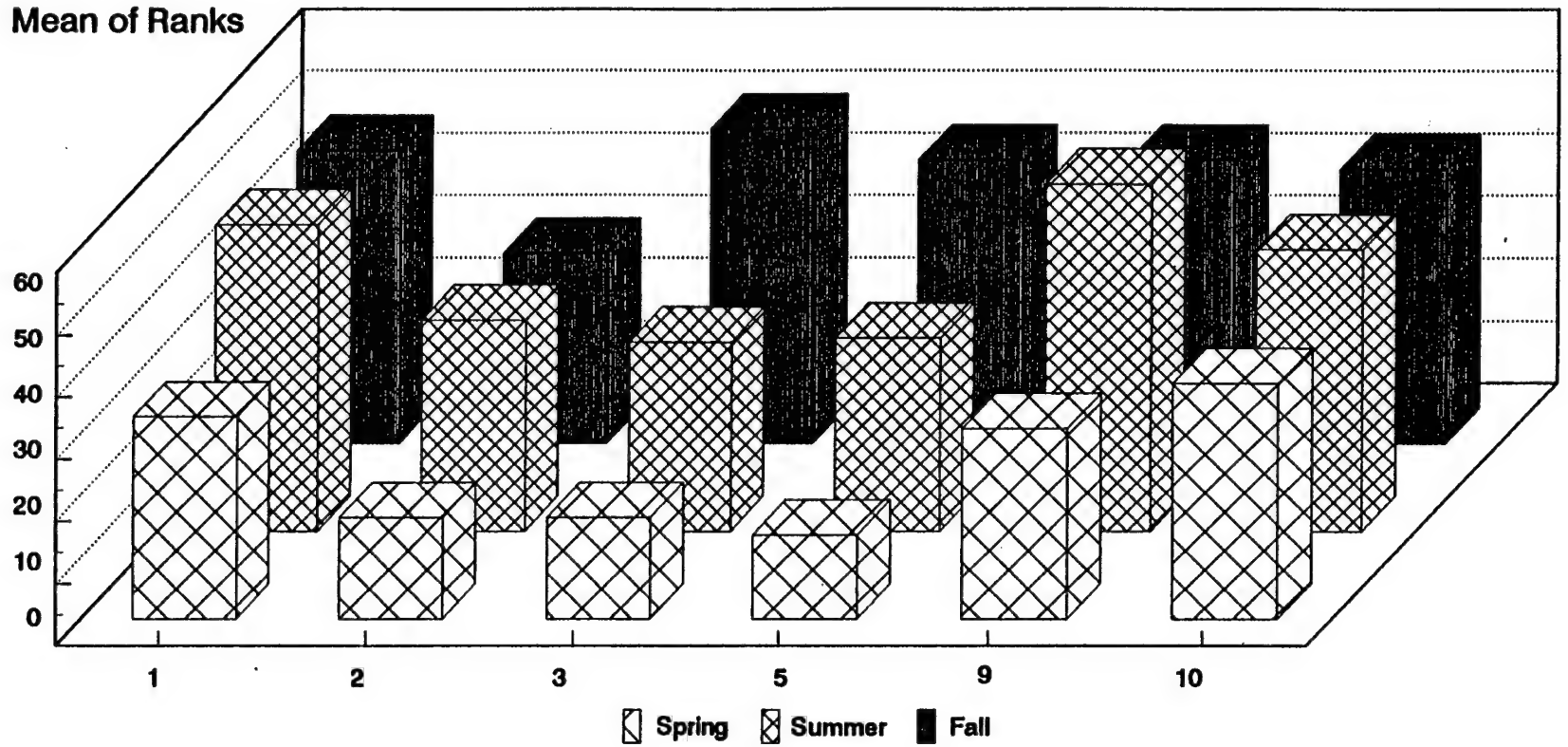


Figure 35. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington in during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance (P > 0.05).



Station Comparison

10 1 9 3 2 5

Season Comparison

Summer Fall Spring

Figure 36. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

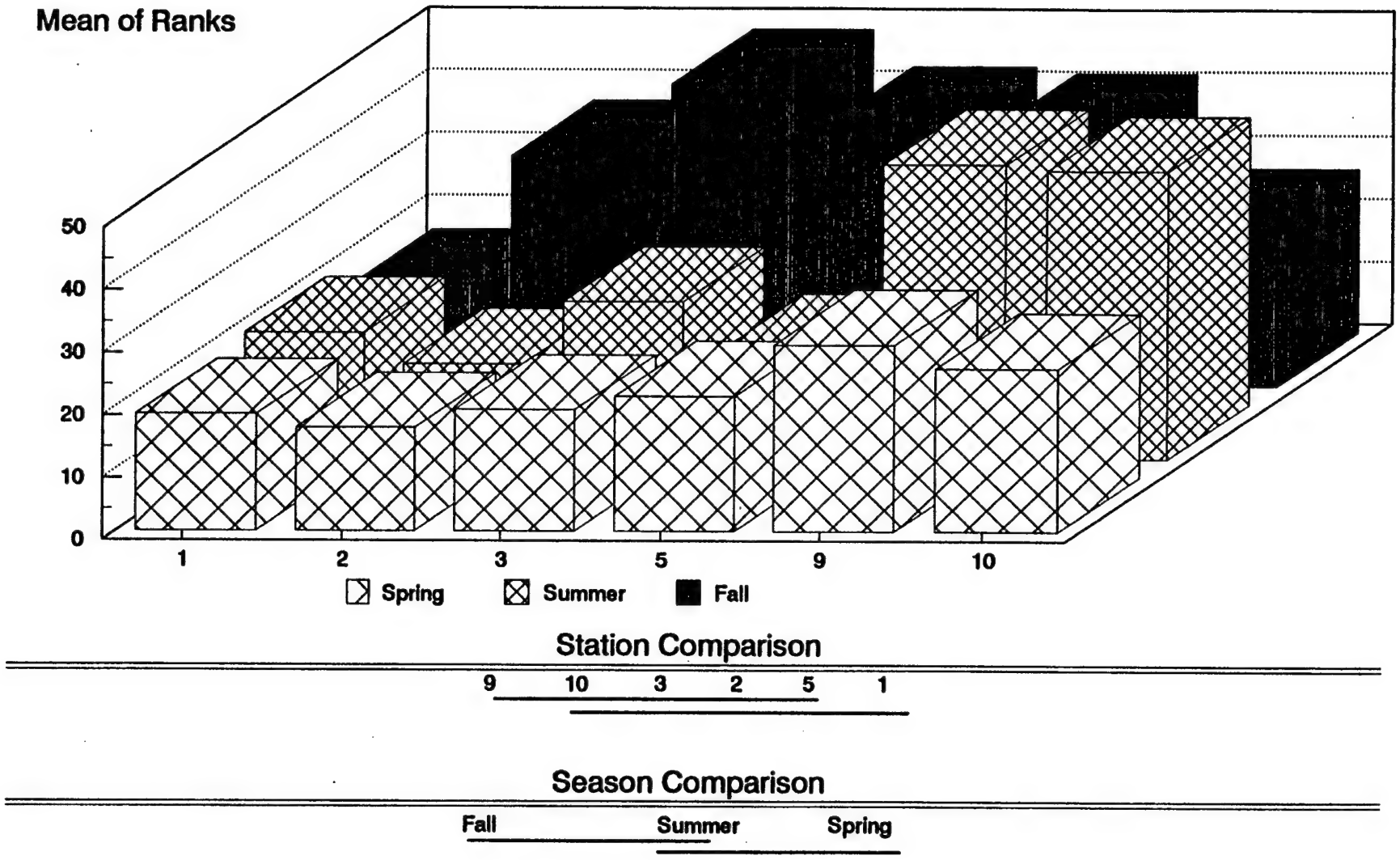


Figure 37. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

< 0.05) difference in catch/effort among stations was between reference station 9 and disposal station 1. The highest catch/effort of smallmouth bass occurred during fall followed by summer and spring. Differences in catch/effort were significant between fall and spring but not between summer.

Channel catfish.- During 1991, catch/effort of channel catfish sampled by gill netting was different between seasons and stations (Figure 38). During spring, the highest catch/effort for channel catfish occurred at reference stations 8 and 6, and catch/effort during fall was highest at reference stations 8 and 5. Differences in catch/effort were significant between these stations and all others sampled. Differences in catch/effort within stations among spring and fall were significant ($P < 0.05$) at reference stations 5 and 6.

White sturgeon.- Abundance of white sturgeon sampled by gill netting during 1991 was highest at deep water reference station 8 followed by disposal station 2 (Figure 39). Differences in catch/effort were not statistically significant among all the shallow water reference and disposal stations. Comparisons of catch/effort at station 8 was significantly ($P < 0.05$) different from other stations, except for station 2. No seasonal effect in catch/effort was observed, as differences in catch/effort between spring and fall were not significant ($P > 0.05$).

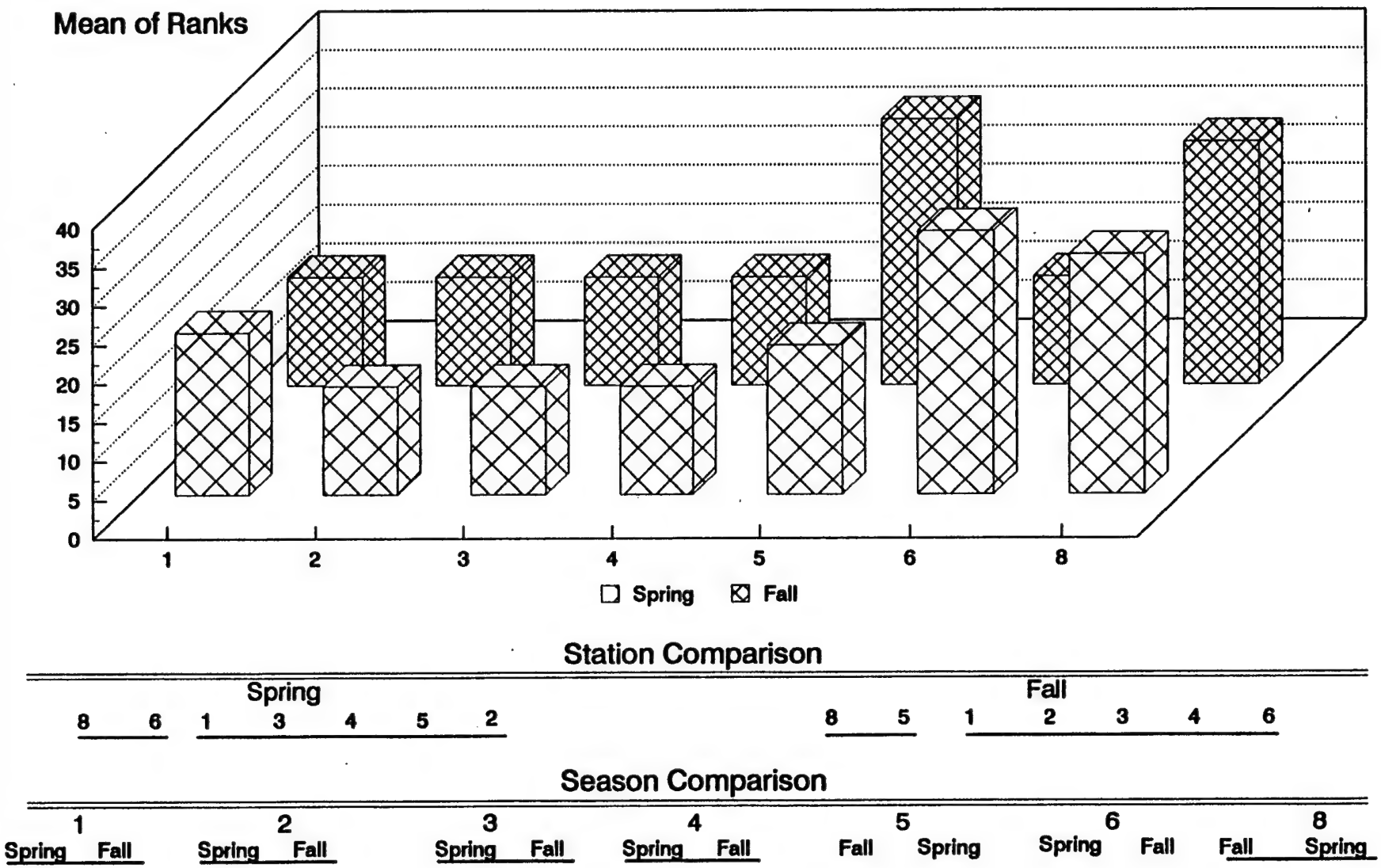


Figure 38. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

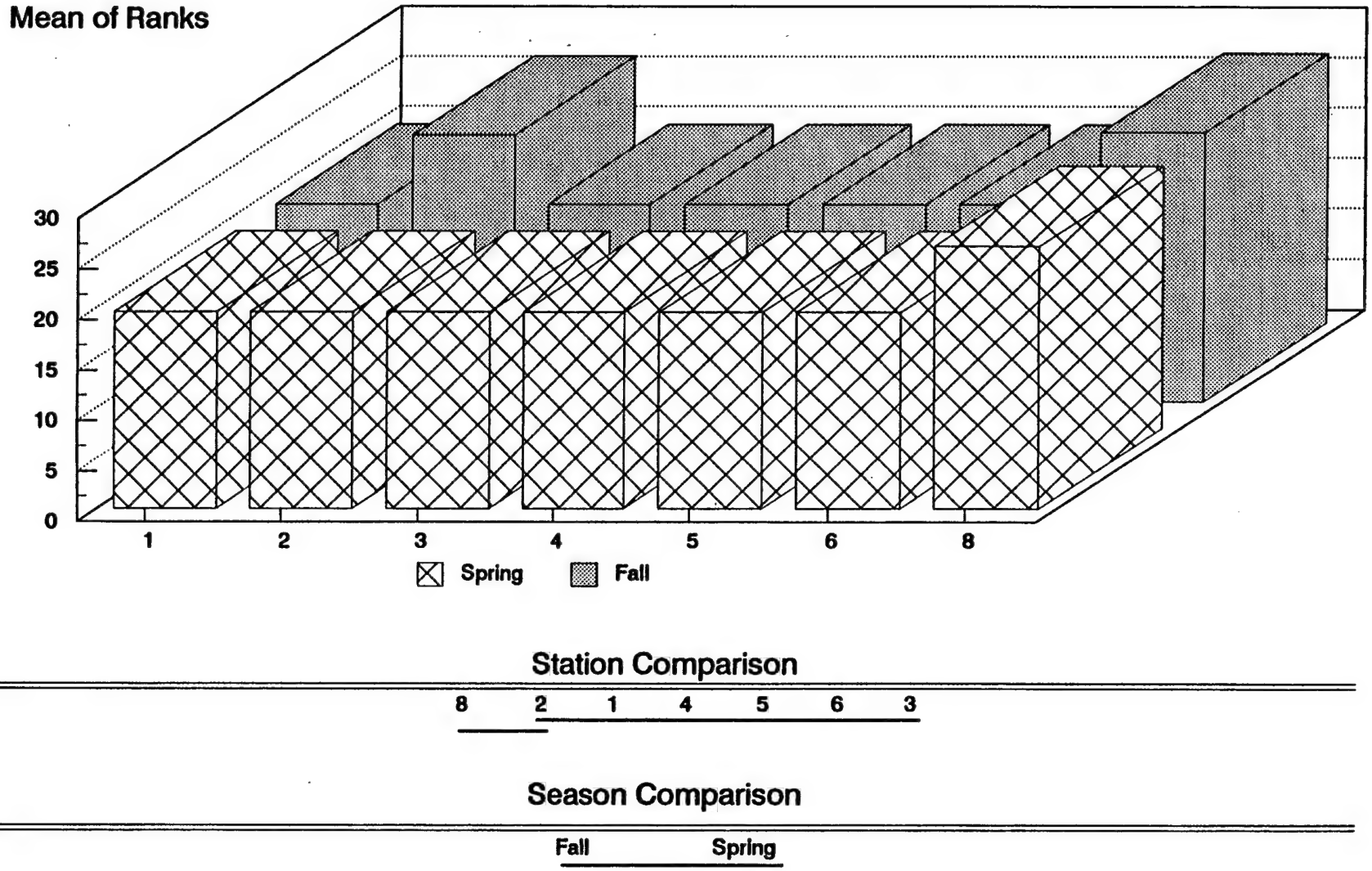


Figure 39. Graphical and statistical comparisons of the mean of ranks for white sturgeon abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1991. Horizontal lines under stations and seasons indicate statistical nonsignificance ($P > 0.05$).

1989-1991

Station and season comparisons of fish abundance were made from 1989-1991. During 1989, dredged material was used to create island disposal stations 1 and 2, therefore, comparison during this 3 year period represent changes that have occurred since the island was created in Lower Granite Reservoir.

Chinook salmon.- The abundance of juvenile chinook salmon based on comparisons of catch/effort by beach seining indicate no significant ($P > 0.05$) difference among reference and disposal stations, or between years (Figure 40). Comparisons of catch/effort were highest at reference stations 3 and 5, whereas the lowest occurred at disposal stations 1 and 2. Annual differences were not significant ($P > 0.05$), however, the highest catch/effort was in 1989 while 1991 had the lowest.

The abundance of juvenile chinook salmon based on comparison of catch/effort by nighttime electrofishing indicated no significant ($P > 0.05$) difference among stations and years (Figure 41). Shallow water reference station 5 had the highest catch/effort followed by disposal station 1. Shallow water reference station 10 had the lowest abundance based on comparisons of catch/effort. Comparison of catch/effort among years decreased from 1989 to 1991, although these differences were not significant ($P > 0.05$).

Since 1989, comparisons of catch/effort for juvenile chinook salmon sampled by surface trawling have been generally consistent within stations (Figure 42). Catch/effort has generally been highest at reference station 5 followed by reference station 6. Abundance of

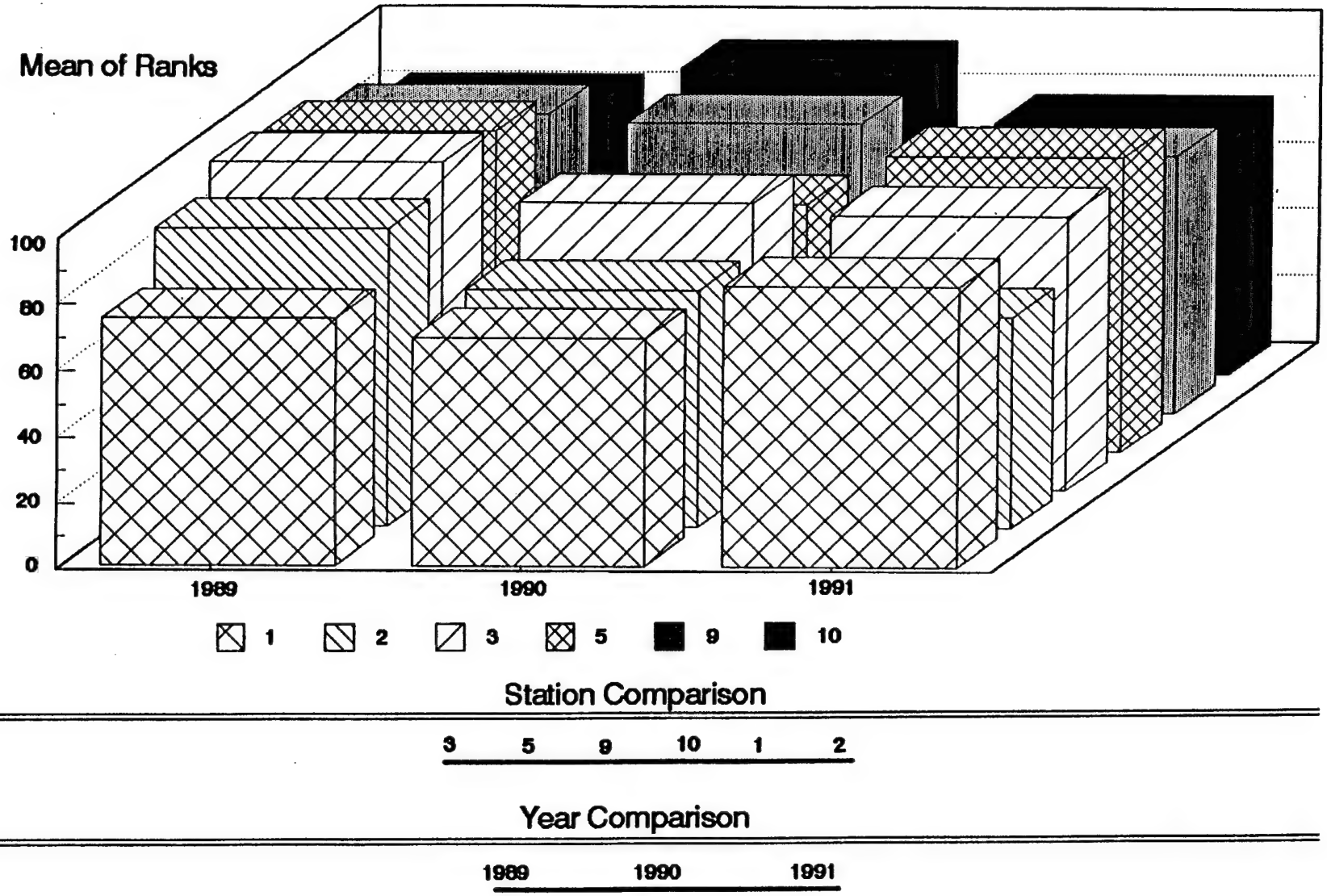


Figure 40. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

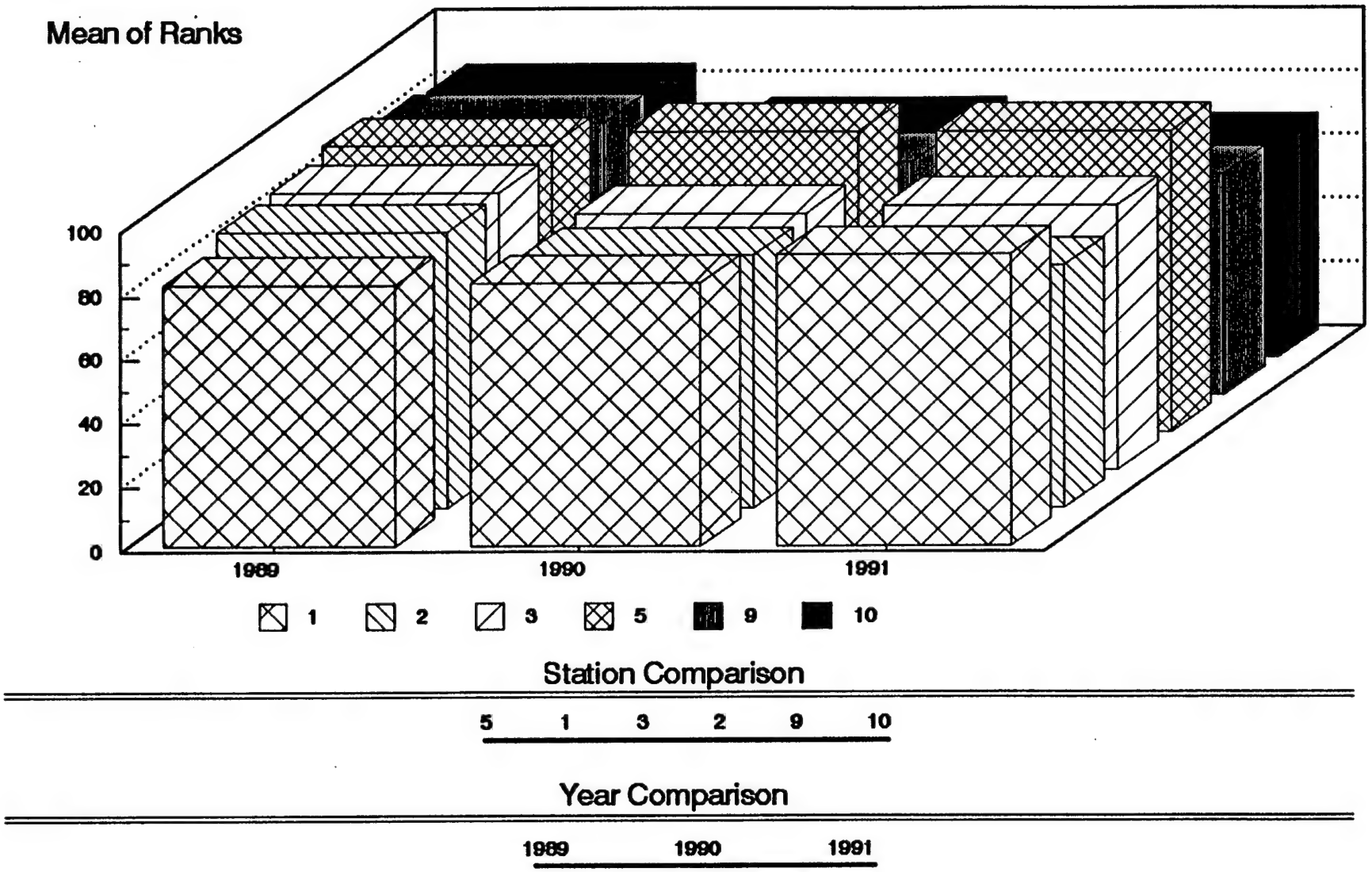
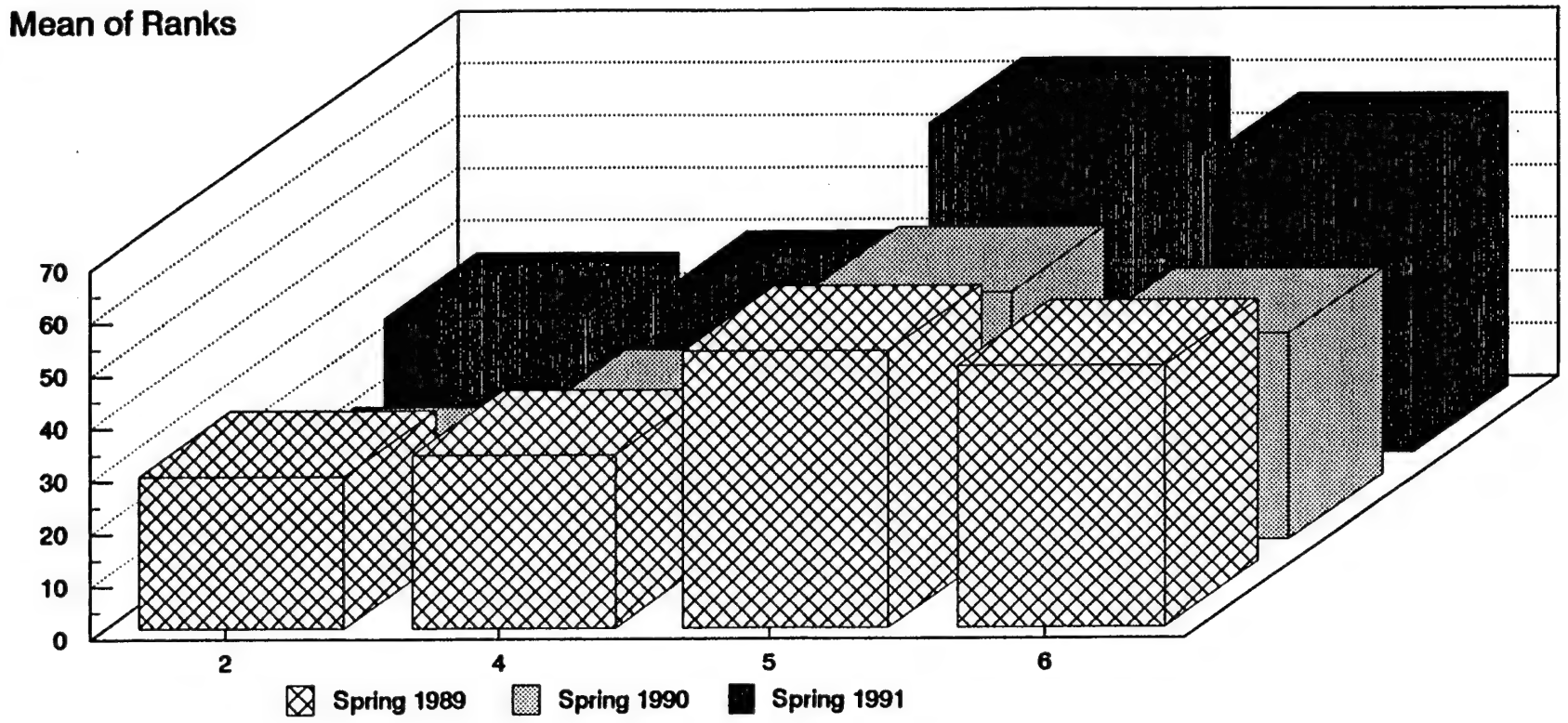


Figure 41. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).



Station Comparison

5 6 4 2

Year Comparison

1991 1989 1990

Figure 42. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by surface trawling in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

juvenile chinook based on comparisons of catch/effort at these stations has been significantly ($P < 0.05$) higher than at disposal stations 4 and 2. Comparisons of catch/effort among years indicated 1991 was the highest, although it was not significantly ($P > 0.05$) different from 1989. During both 1991 and 1989 comparisons of catch/effort were significantly ($P < 0.05$) higher than 1990.

Steelhead.- The abundance of juvenile steelhead based on comparison of catch/effort by beach seining was significantly ($P < 0.05$) different among stations and years (Figure 43). Differences in catch/effort for juvenile steelhead were significantly higher at reference station 9 than at other shallow water reference and disposal stations. The lowest catch/effort was at disposal station 1 which was significantly lower than the shallow water reference stations. Catch/effort was significantly higher during 1989 than in 1990 and 1991.

The abundance of juvenile steelhead sampled by nighttime electrofishing from 1989-1991 was generally higher in the lower portion of Lower Granite Reservoir (Figure 44). Catch/effort was significantly ($P < 0.05$) higher at reference station 9 than at other reference and disposal stations, except station 10 which was statistically similar. The abundance of juvenile steelhead was generally lower at disposal stations 1 and 2.

Differences in abundance of juvenile steelhead based on comparisons of catch/effort among years were not statistically significant ($P > 0.05$; Figure 44). Abundance in 1991 was intermediate to the highest in 1990 and the lowest in 1989.

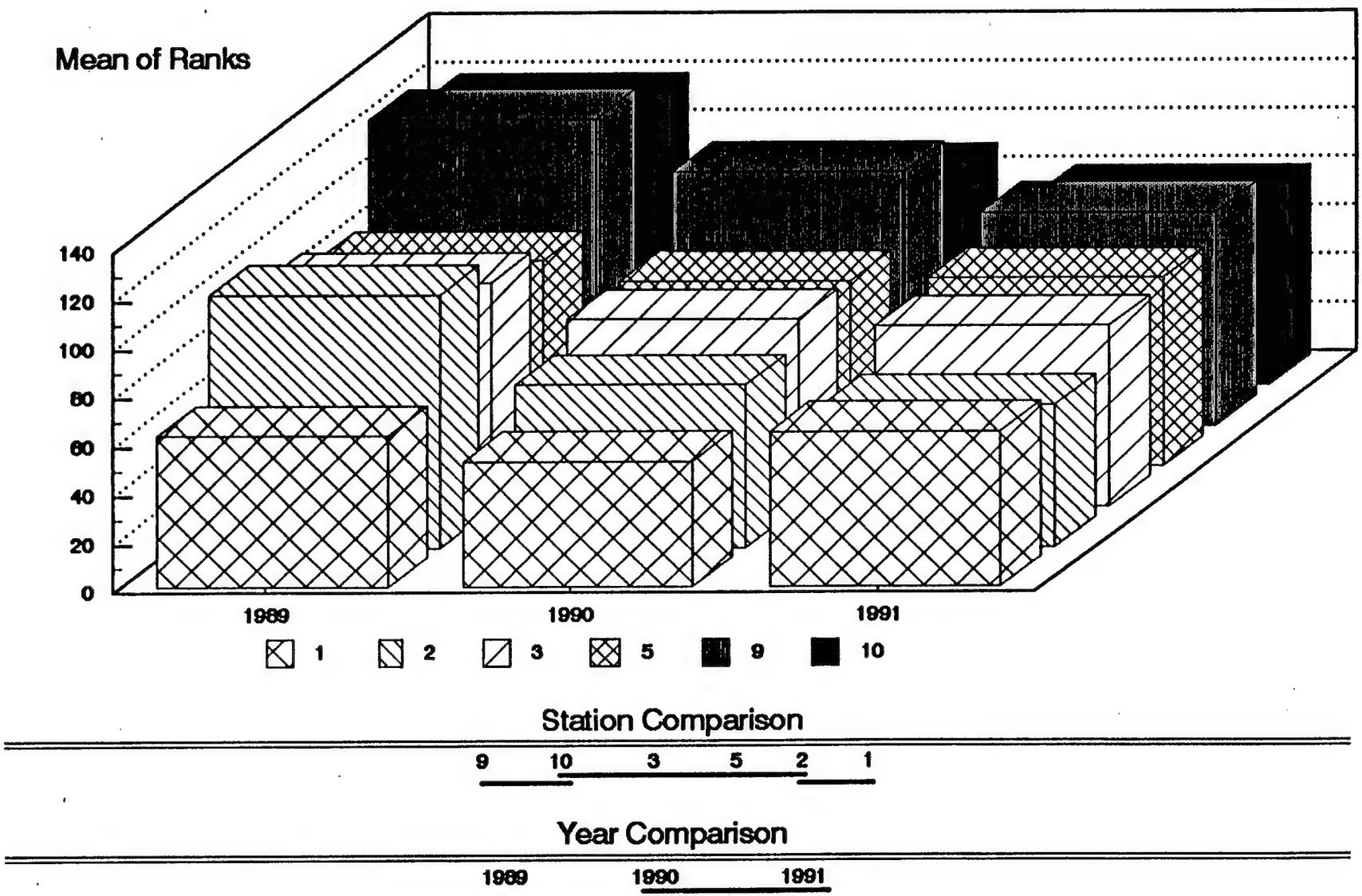


Figure 43. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

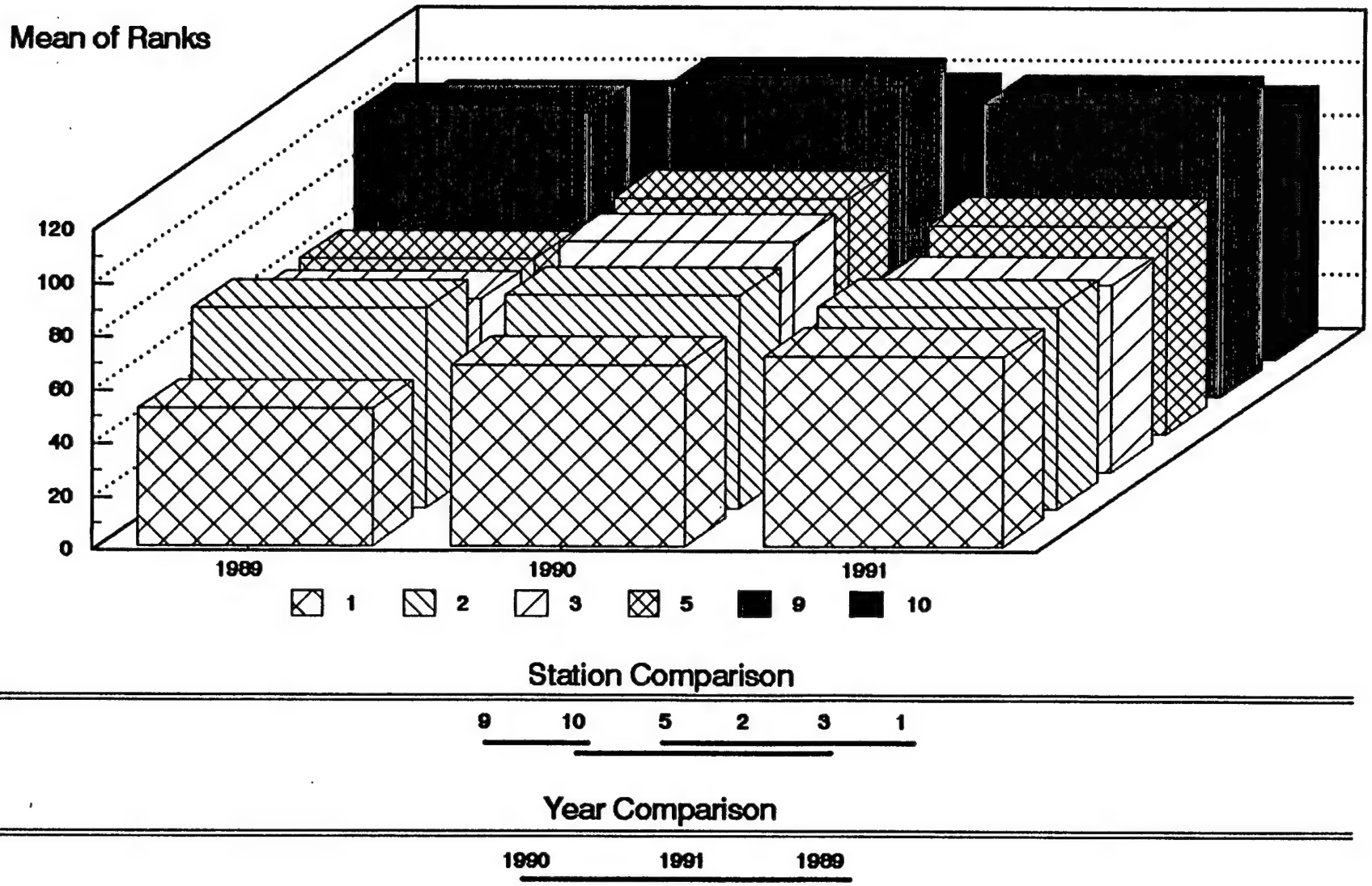


Figure 44. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

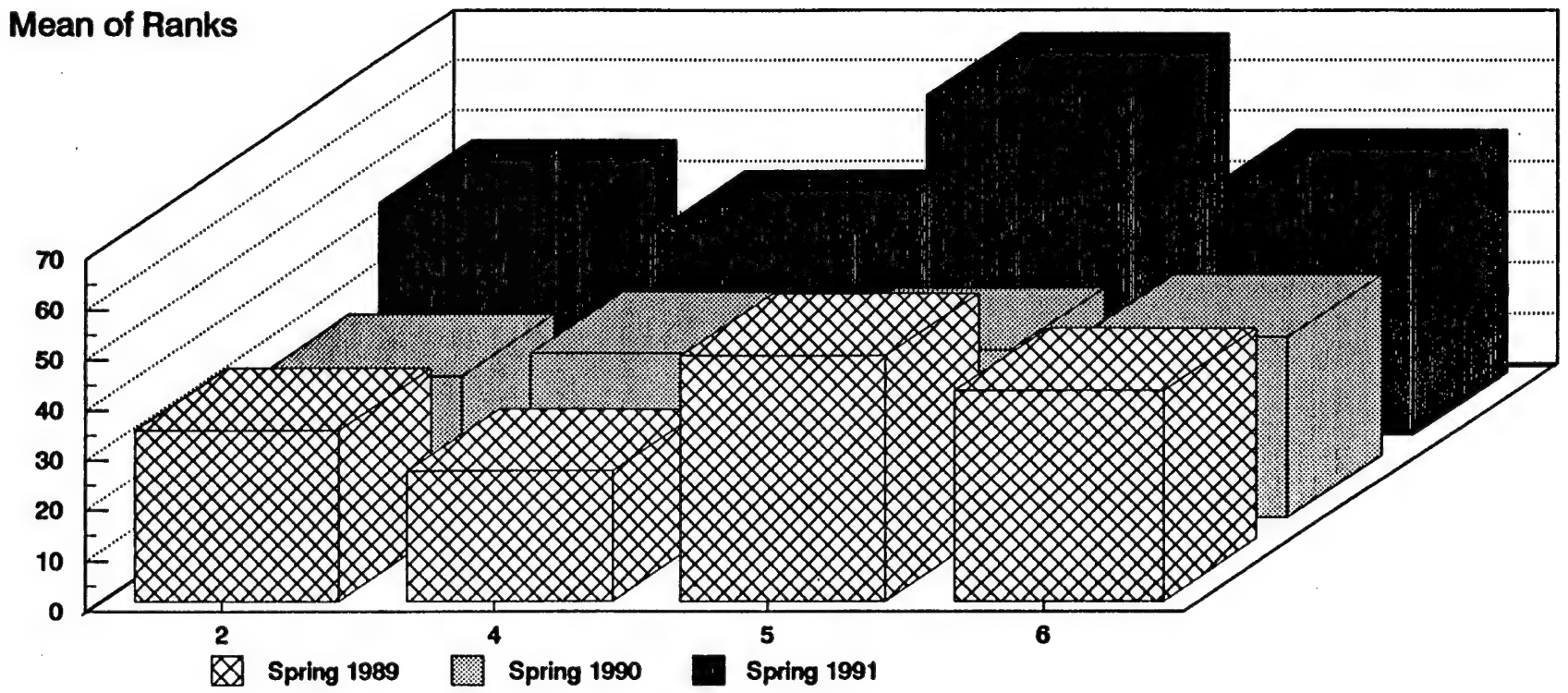
Since 1989, catch/effort of juvenile steelhead sampled by surface trawling has been highest at reference station 5 followed by reference station 6 (Figure 45). Catch/effort was lowest at disposal station 4. Comparisons of catch/effort at reference station 5 were significantly higher than at disposal station 4, although comparisons of catch/effort among other stations were not significant ($P > 0.05$).

Differences in catch/effort among years for juvenile steelhead sampled by surface trawling was highest in 1991 followed by 1989 and 1990 (Figure 45). Statistically, differences in catch/effort during 1991 were significantly ($P < 0.05$) higher than in 1990 but not between 1989 and 1990 and 1991.

Northern squawfish.- During 1989-1991, differences in catch/effort for northern squawfish sampled by gill nets were significant ($P < 0.05$) between stations and years (Figure 46). Differences in catch/effort among stations were scattered and generally showed that adult and subadult squawfish caught by gill nets were highest in abundance at shallow (5) and mid-depth (6) reference stations. These were followed by disposal stations 1 and 2, however, catches of squawfish were lowest at mid-depth disposal station 4.

Comparisons of catch/effort among stations for northern squawfish sampled by gill netting were highest in 1991 and 1989 followed by 1990 (Figure 46). Differences between 1991 and 1989 were significantly ($P < 0.05$) higher than those in 1990.

The abundance of northern squawfish sampled by beach seining based on comparisons of catch/effort among stations and years was scattered



Station Comparison

5 6 2 4

Year Comparison

1991 1989 1990

Figure 45. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by surface trawling in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

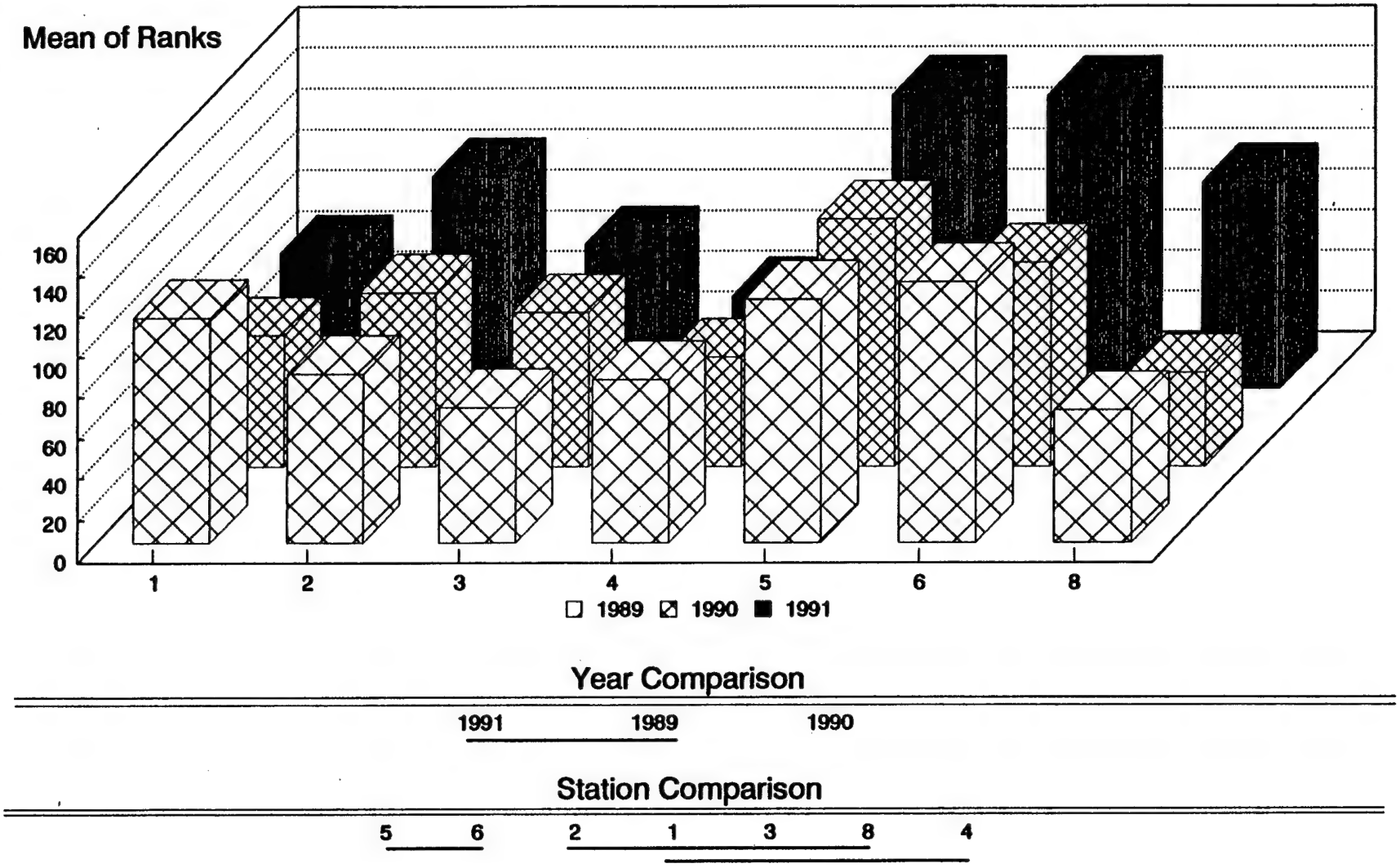


Figure 46. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

(Figure 47). Comparisons of catch/effort for squawfish were highest at reference stations 3 and 10 and lowest at disposal stations 1 and 2 and reference station 9. There was no significant difference between stations 3 and 10, although they were significantly ($P < 0.05$) higher than the other stations.

Annual differences in catch/effort for northern squawfish sampled by beach seining from 1989-1991 were highest in 1989 followed by 1991 and 1990 (Figure 47). These differences were only significant ($P < 0.05$) between 1989 and 1990.

The abundance of northern squawfish sampled by nighttime electrofishing has generally been similar among reference and disposal stations and years (Figure 48). Reference stations 5, 3 and 10 and disposal station 1 had the highest abundance of northern squawfish. The highest abundance of northern squawfish was found during 1991. Comparison of catch/effort data suggest squawfish abundance increased from 1989 to 1991.

Smallmouth bass.- Comparisons of catch/effort for smallmouth bass sampled by gill netting indicated catches were highest at disposal station 1 followed by shallow water reference stations 3 and 5 (Figure 49). However, differences in catch/effort among shallow water disposal and reference stations were not significantly ($P > 0.05$) different.

Catches of smallmouth bass sampled by gill netting indicated an abundance of bass in 1991 (Figure 49). Abundance in 1991 was significantly ($P < 0.05$) higher than 1989 and 1990.

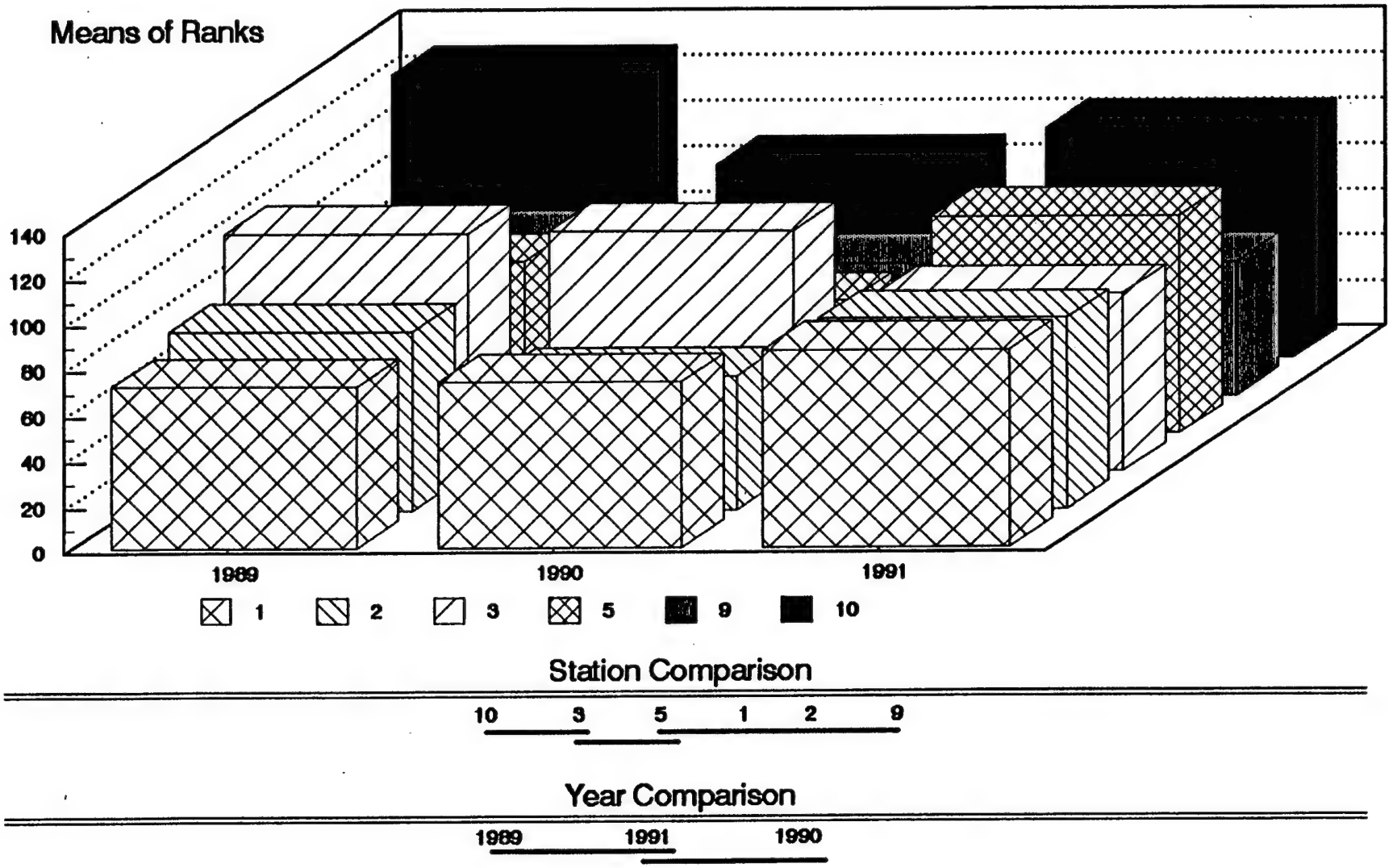


Figure 47. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

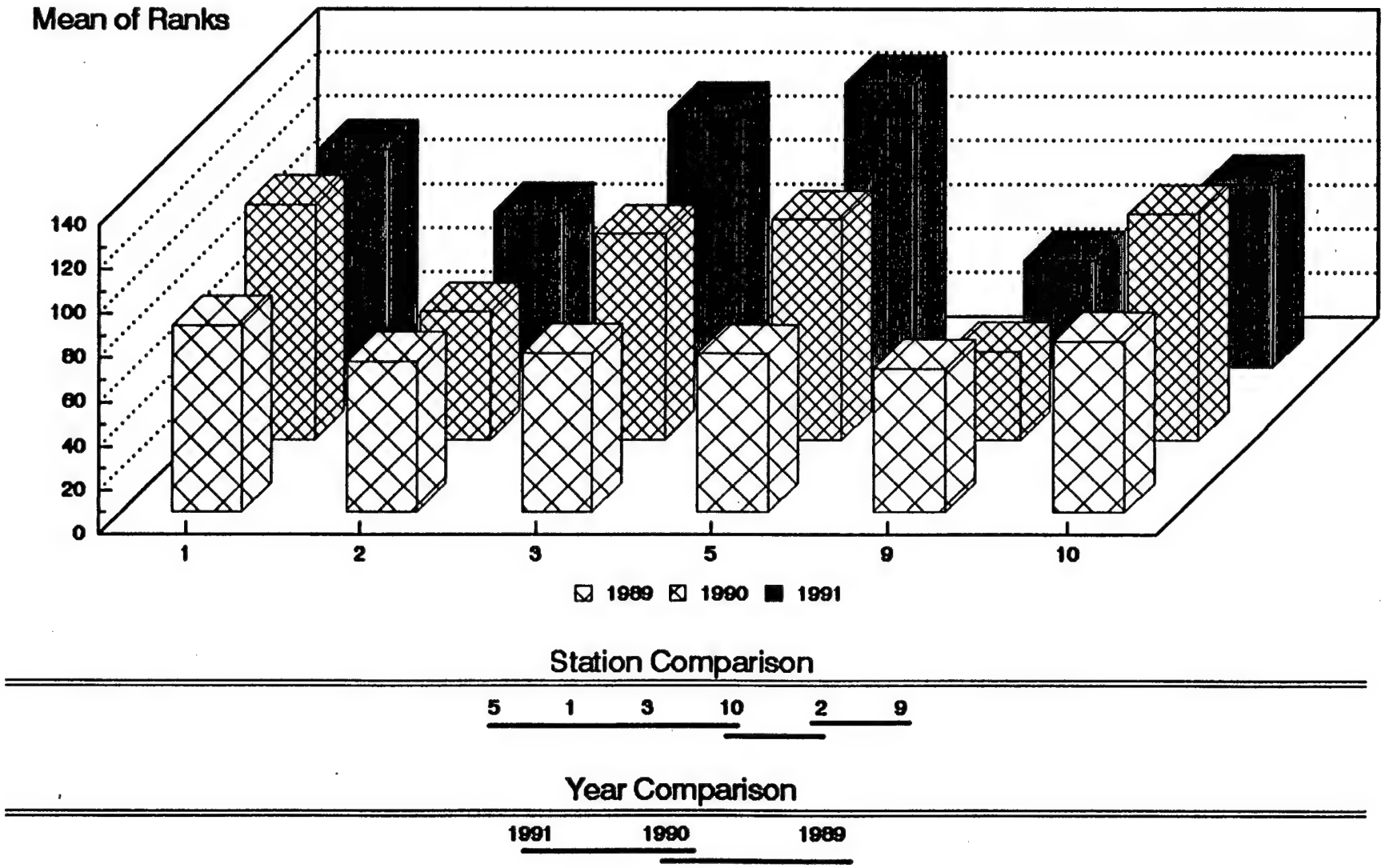


Figure 48. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

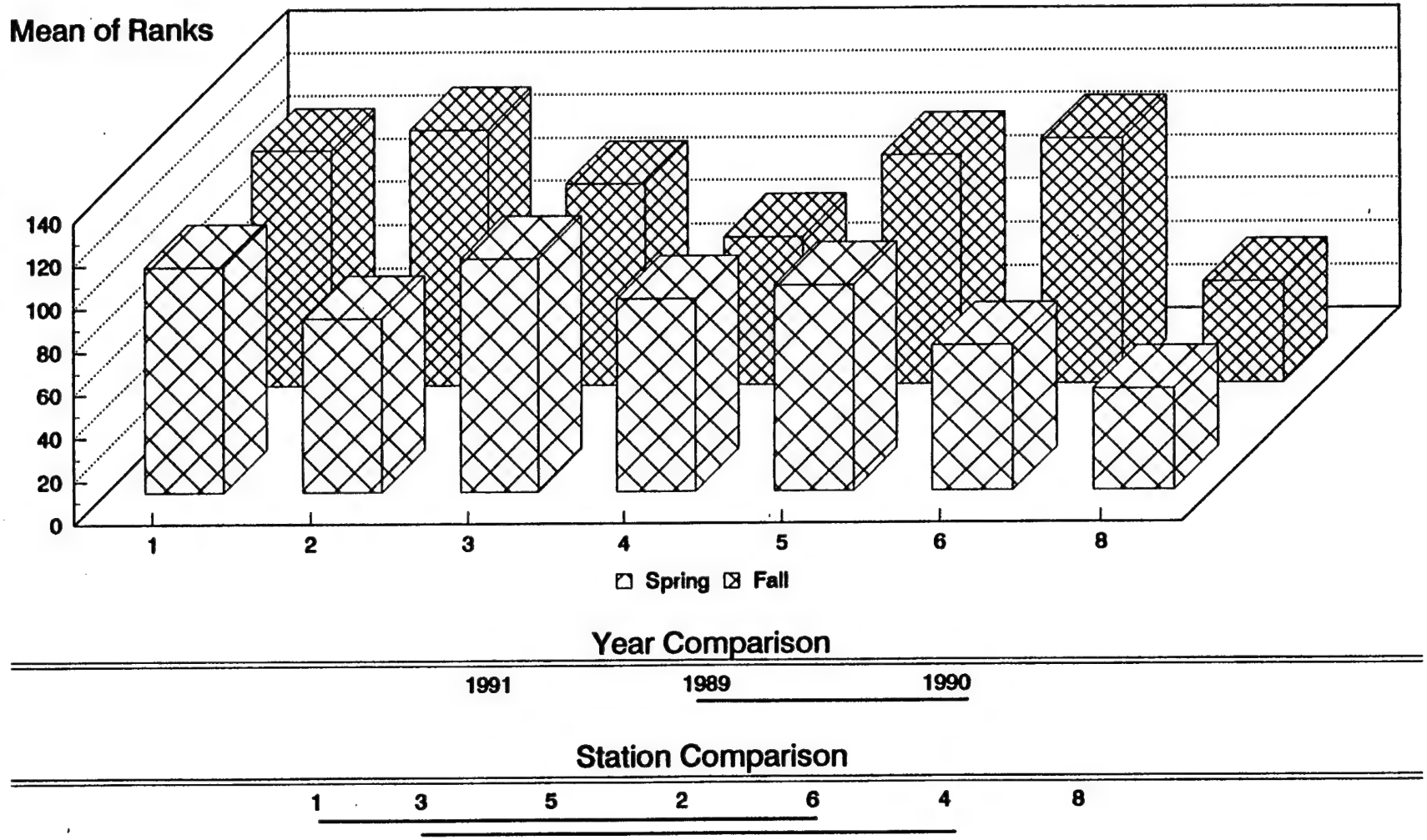


Figure 49. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

Catches of smallmouth bass sampled by gill nets were similar between spring and fall (Figure 50). Seasonal abundance of smallmouth bass varied among stations during 1989-1991. Each fall from 1989 through 1991 bass generally were caught in higher abundance at stations with deeper waters, whereas abundance in shallow waters was higher during spring.

Comparisons of catch/effort of smallmouth bass based on beach seining indicated few station differences and no annual differences during 1989-1991 (Figure 51). Abundance of smallmouth bass was highest at reference station 10 followed by reference station 9. Significant ($P < 0.05$) differences of abundance between stations were found, but they were scattered and indicated abundance of smallmouth bass was generally lower at the disposal stations. Annual differences in catch/effort were not significant ($P > 0.05$). The highest catch/effort was found in 1990 and was followed by 1991 and 1989.

Comparisons of catch/effort for smallmouth bass based on nighttime electrofishing were different among reference and disposal stations and years (Figure 52). Catch/efforts of smallmouth bass at reference stations 9 and 10 were significantly ($P < 0.05$) higher than disposal stations 1 and 2. Abundance at reference station 5 was not statistically ($P > 0.05$) different from disposal stations 1 and 2.

Annual differences in abundance of smallmouth bass sampled by nighttime electrofishing indicate the highest abundance occurred in 1991 followed by 1990 and 1989 (Figure 52). Catch/effort of smallmouth bass

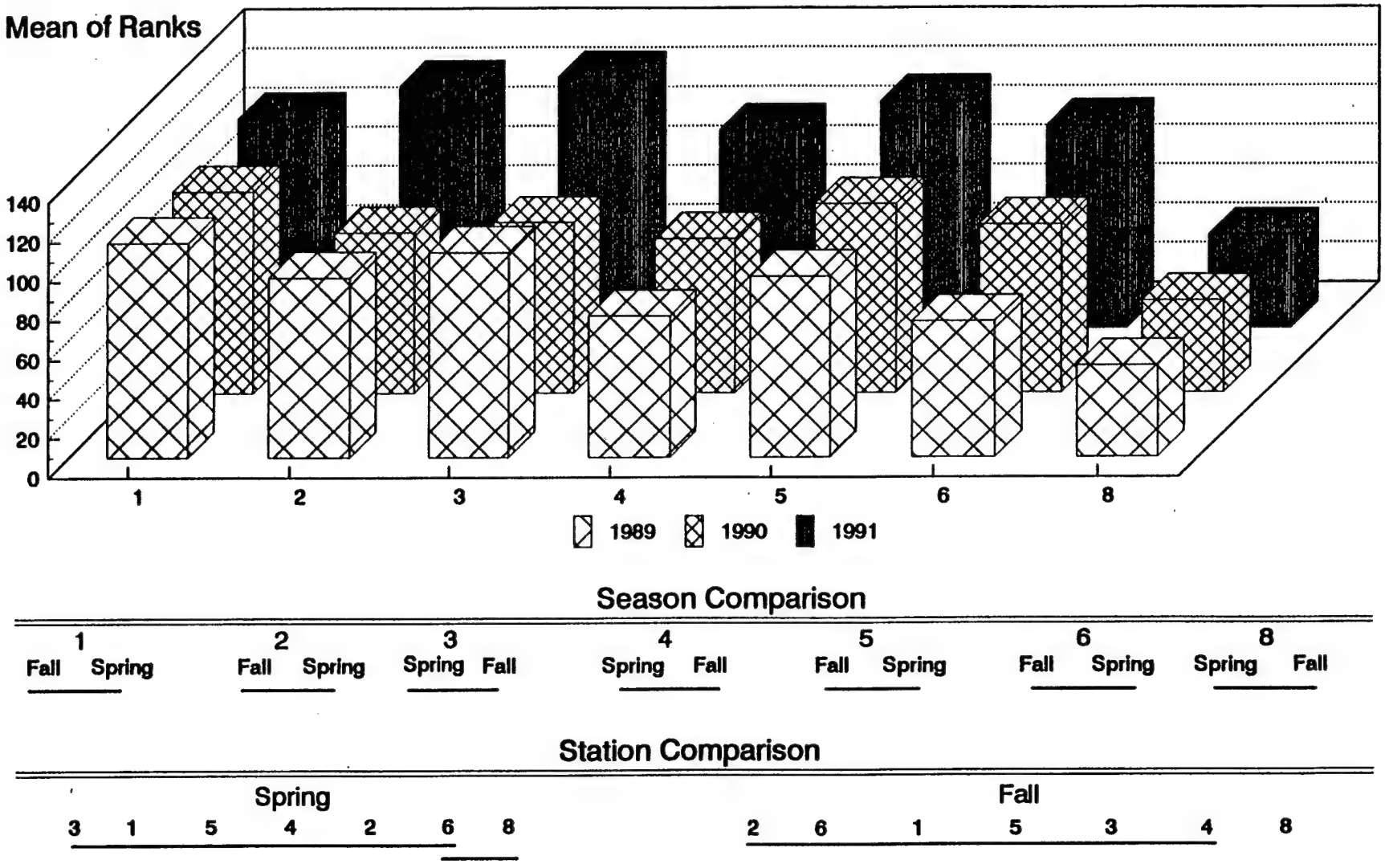


Figure 50. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under seasons and stations indicate statistical nonsignificance ($P > 0.05$).

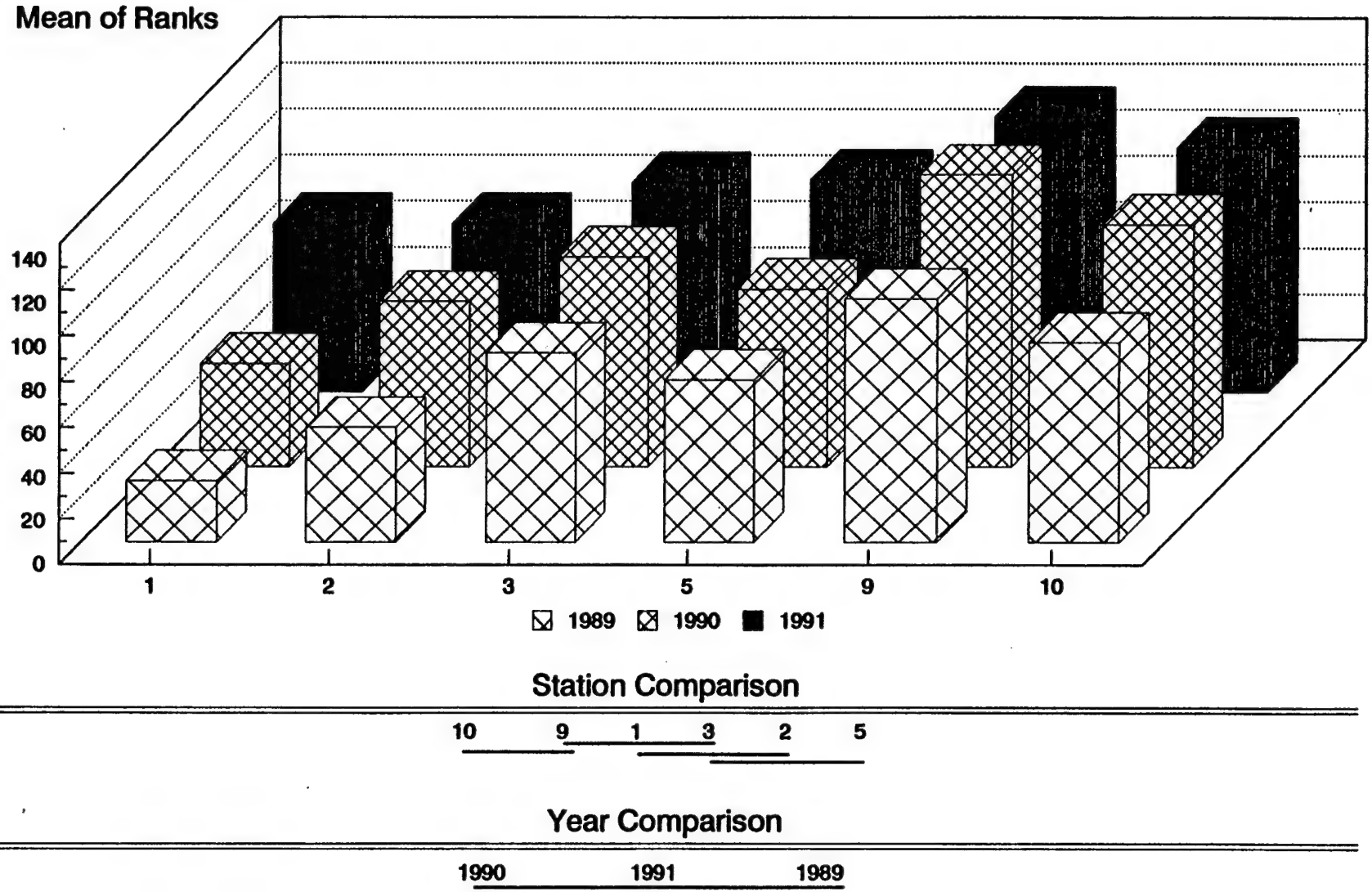


Figure 51. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

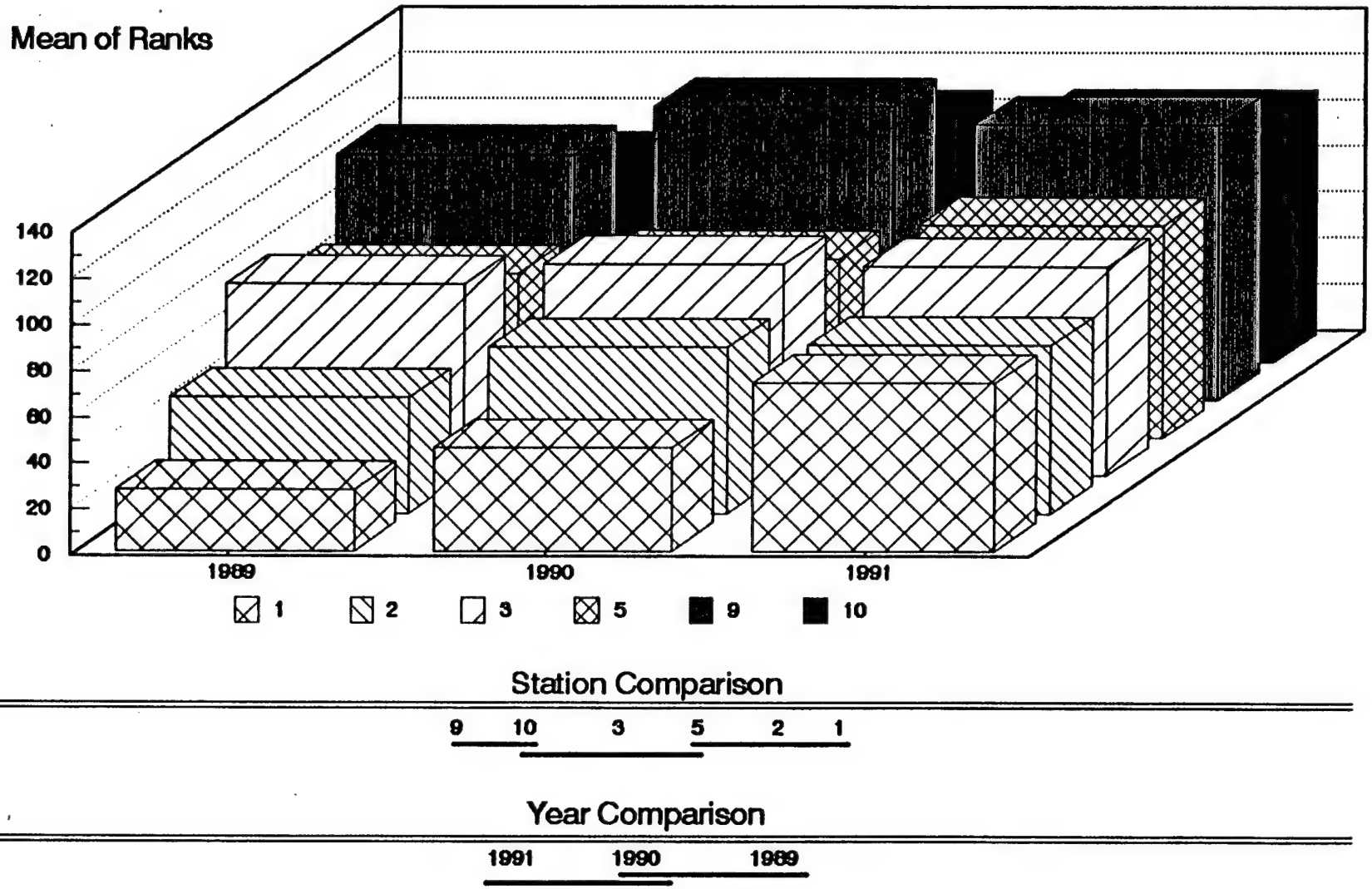


Figure 52. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

was significantly ($P < 0.05$) higher in 1991 than in 1989 but was similar to 1990.

Channel catfish.- Abundance of channel catfish by gill netting at all stations has declined since 1989 (Figure 53). Catch/effort of catfish was significantly ($P < 0.05$) higher in 1989 than 1990 and 1991. Catches from 1991 were lowest of the 3 years. Reference stations 8 and 5 exhibited the highest catch/effort. Catches of channel catfish have generally been higher at the reference stations than at the disposal stations, as mid-depth disposal station 4 was the lowest.

Differences in catch/effort between spring and fall were found at shallow water reference station 3 and mid-depth reference station 6 (Figure 54). No significant ($P > 0.05$) differences of catch/effort for northern squawfish were found at the disposal stations. No trends in abundance of channel catfish have been found during 1989-1991, however abundance is generally higher at deep water reference station 8 and shallow water reference station 5.

White sturgeon.- Captures of white sturgeon by gill netting were consistently highest at deep water reference station 8 during 1989-1991 (Figure 55). Differences in catch/effort of white sturgeon were significantly ($P < 0.05$) higher at reference station 8 than other stations. Catches at disposal stations 1 and 2 were higher than the reference stations, except for reference station 5, although these differences were not significant ($P > 0.05$).

Seasonal differences in abundance of white sturgeon were found at reference station 8 (Figure 55). Catches at most stations generally

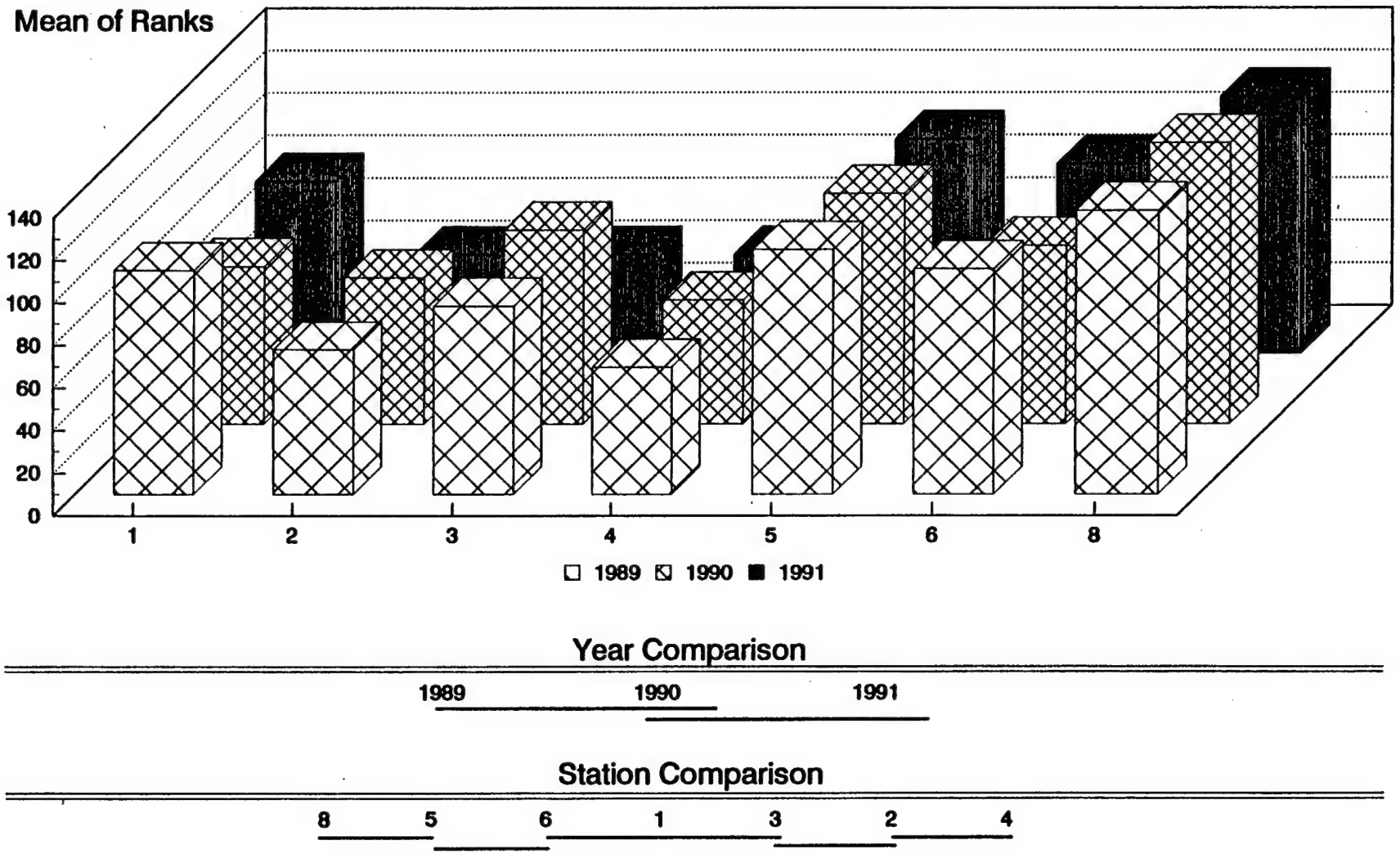


Figure 53. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

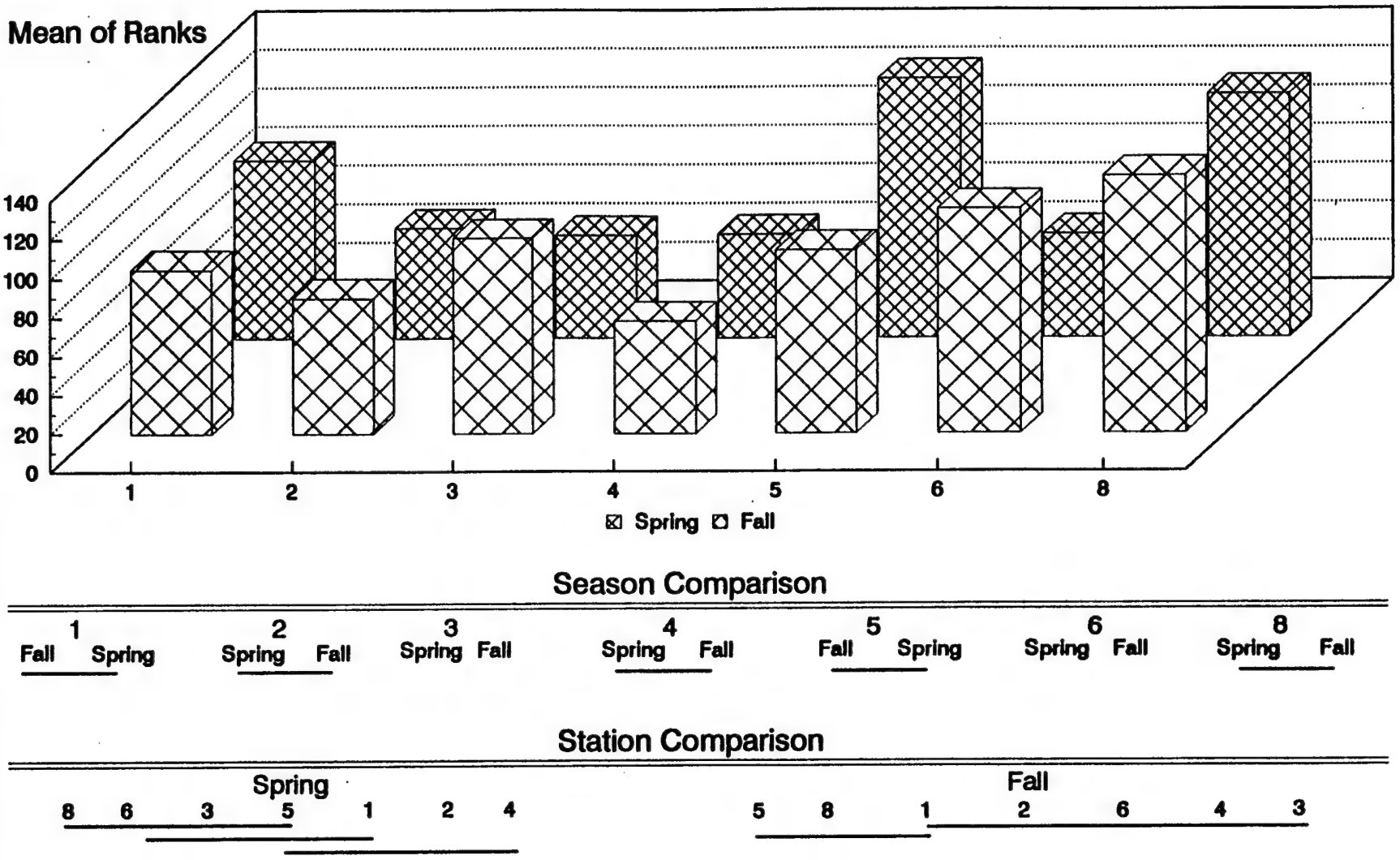
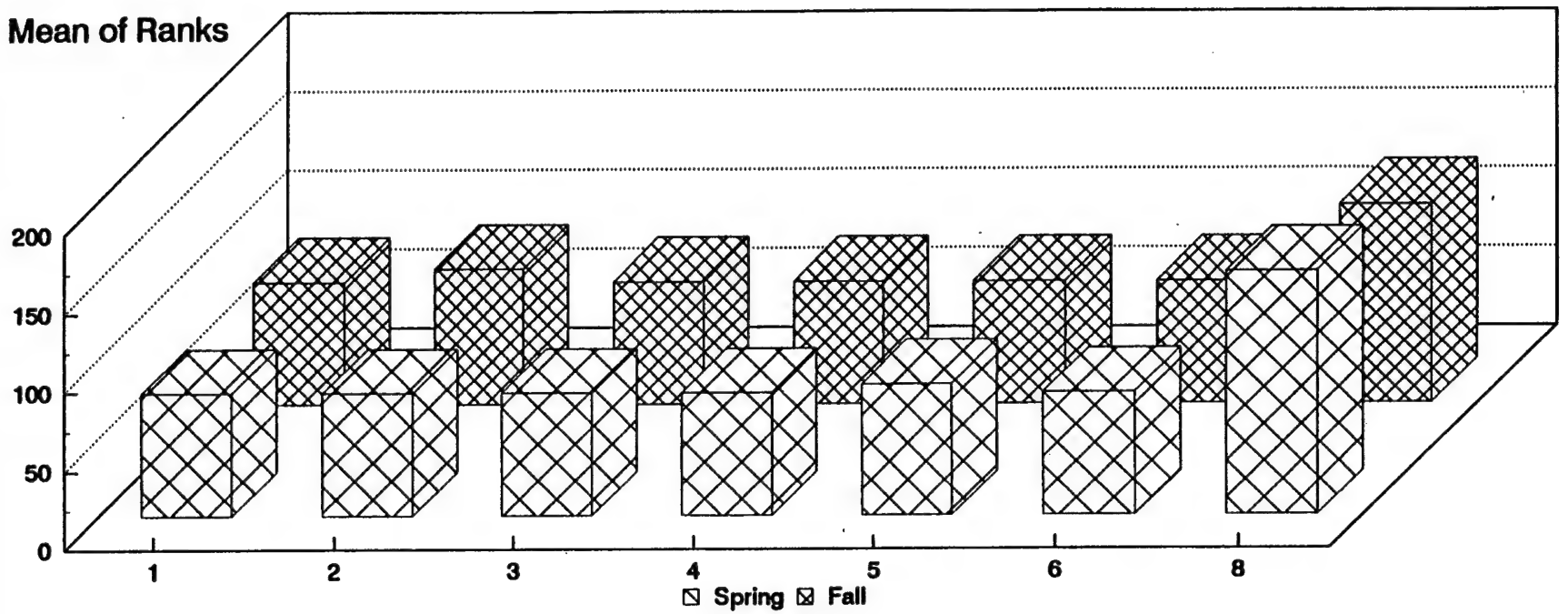


Figure 54. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under seasons and stations indicate statistical nonsignificance ($P > 0.05$).



Season Comparison

1	2	3	4	5	6	8
Spring Fall	Spring Fall	Fall Spring	Spring Fall	Spring Fall	Spring Fall	Spring Fall

Station Comparison

Spring							Fall						
8	5	1	2	3	4	6	8	2	1	3	4	5	6

Figure 55. Graphical and statistical comparisons of the mean of ranks for white sturgeon abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under seasons and stations indicate statistical nonsignificance ($P > 0.05$).

were higher during spring, although only significantly ($P < 0.05$) higher at station 8. Changes in white sturgeon abundance from 1989 to 1991 based on comparison of catch/effort sampled by gill netting were not significant at any of the stations, except station 8 where catches declined significantly from 1989-1991 (Figure 56).

1988-1991

Comparisons of catch/effort from 1988-1991 provide a metric of "long-term" changes in the fish community. In-water disposal was initiated in 1988 at mid-depth disposal station 4. Changes in the fish community that may have resulted during 1988-1991 would probably be reflected in statistical comparisons between these years.

Chinook salmon.- There were no significant ($P > 0.05$) differences in catch/effort of juvenile chinook sampled by beach seining among stations for 1988-1991 (Figure 57). Catches at shallow water reference stations 3 and 10 were higher than those at stations 9 and 5.

Changes in abundance of juvenile chinook salmon from 1988-1991 based on comparison of catch/effort by beach seining were few (Figure 57). The highest catches were made in 1989 followed by 1990, while catches in 1988 were lowest. Differences in catch/effort were significant ($P < 0.05$) between 1989 and 1988, however there were no significant ($P > 0.05$) differences among the other years.

Since 1988, comparisons of catch/effort for juvenile chinook salmon sampled by nighttime electrofishing were statistically similar among years, however, comparisons among stations were statistically

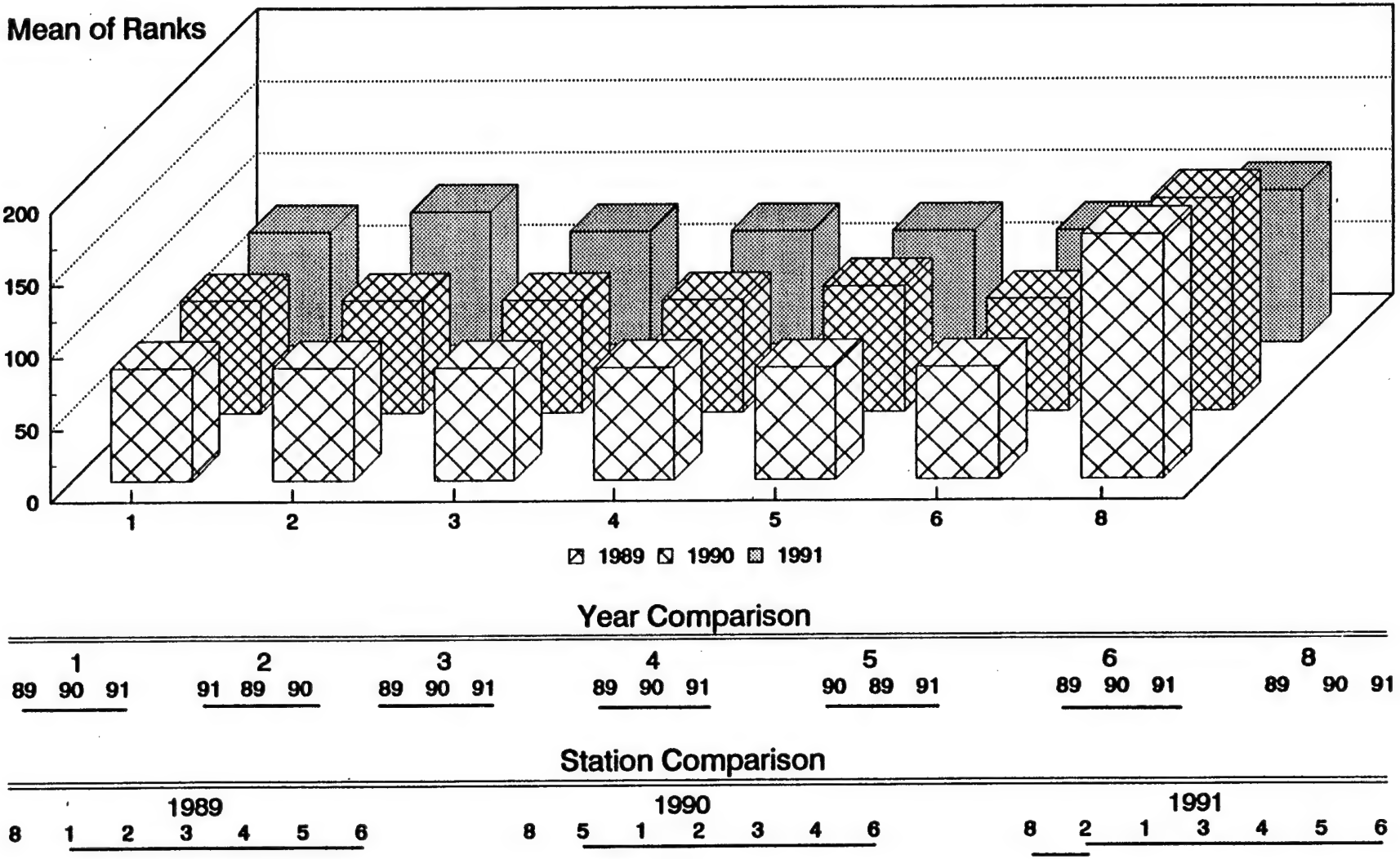


Figure 56. Graphical and statistical comparisons of the mean of ranks for white sturgeon abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

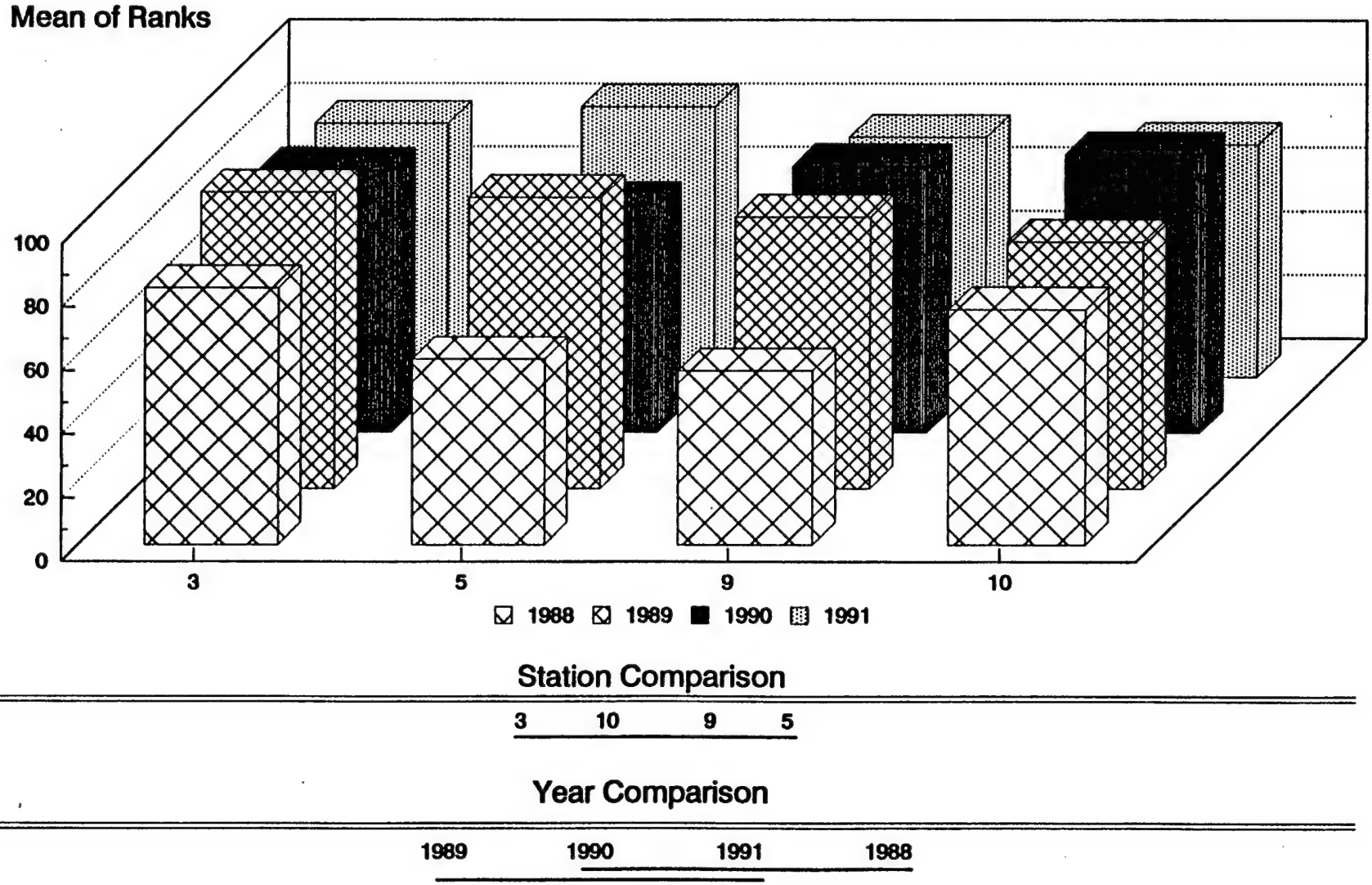


Figure 57. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

different (Figure 58). Abundance of juvenile chinook salmon was significantly ($P < 0.05$) higher at reference station 5 than at reference stations 9 and 10. However, abundance at reference station 3 was not statistically ($P > 0.05$) different from stations 5, 9 and 10. Although year comparisons were not statistically different, 1989 had the highest abundance and 1988 had the lowest.

Steelhead.- Comparisons of catch/effort of juvenile steelhead by beach seining indicated few differences among stations and years for 1988-1991 (Figure 59). The highest catch/effort occurred at reference stations 10 and 9. Both stations are located in the lower portion of Lower Granite Reservoir (RM 110-111). Catches from these stations were significantly ($P < 0.05$) higher than those from station 5 (RM 127) which is located approximately 15 miles upstream.

Catches of juvenile steelhead during 1988 were highest and catches in 1991 were lowest; these differences were significant ($P < 0.05$; Figure 59). Catches in 1989 and 1990 were between those of 1988 and 1991.

Differences in abundance of catch/effort of juvenile steelhead based on nighttime electrofishing at the reference stations occurred among stations and years (Figure 60). Abundance was highest at stations 9 and 10. Differences in abundance were significant ($P < 0.05$) between stations 9 and 10, and 3 and 5.

Annual differences in catch/effort of juvenile steelhead sampled by nighttime electrofishing were slight, as 1988 captures were significantly ($P < 0.05$) different than those from 1989-1991 (Figure

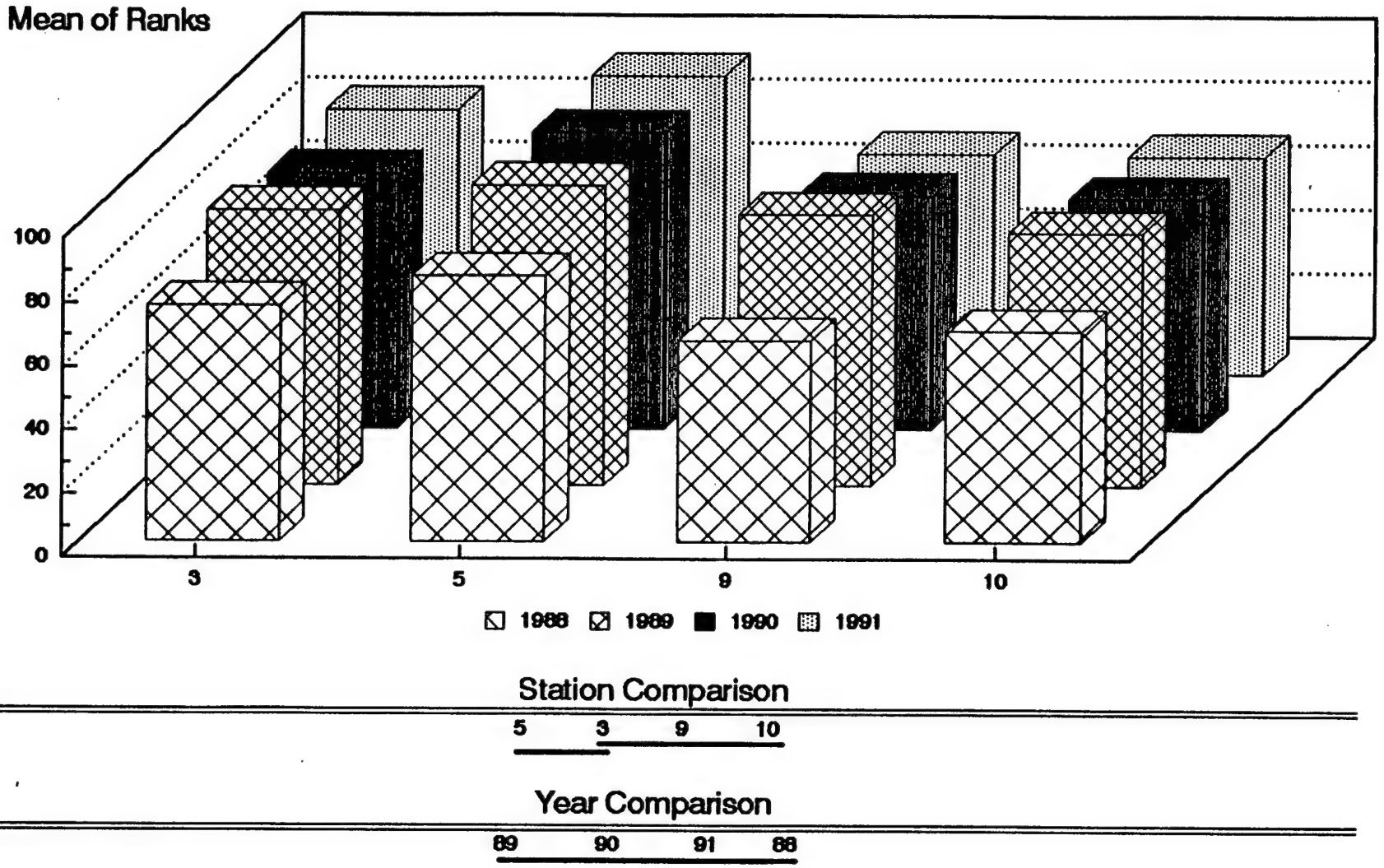


Figure 58. Graphical and statistical comparisons of the mean of ranks for juvenile chinook salmon abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

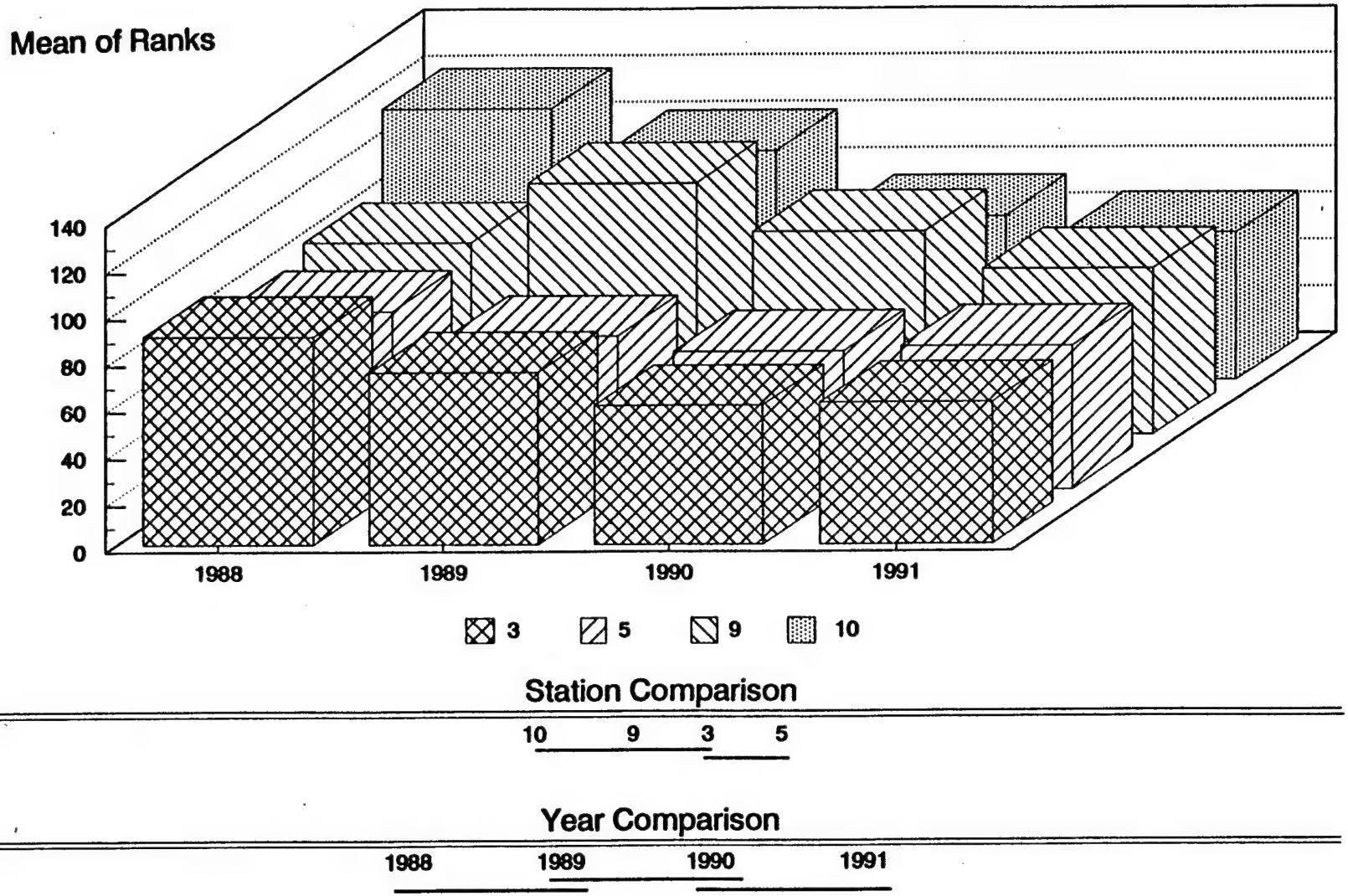


Figure 59. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

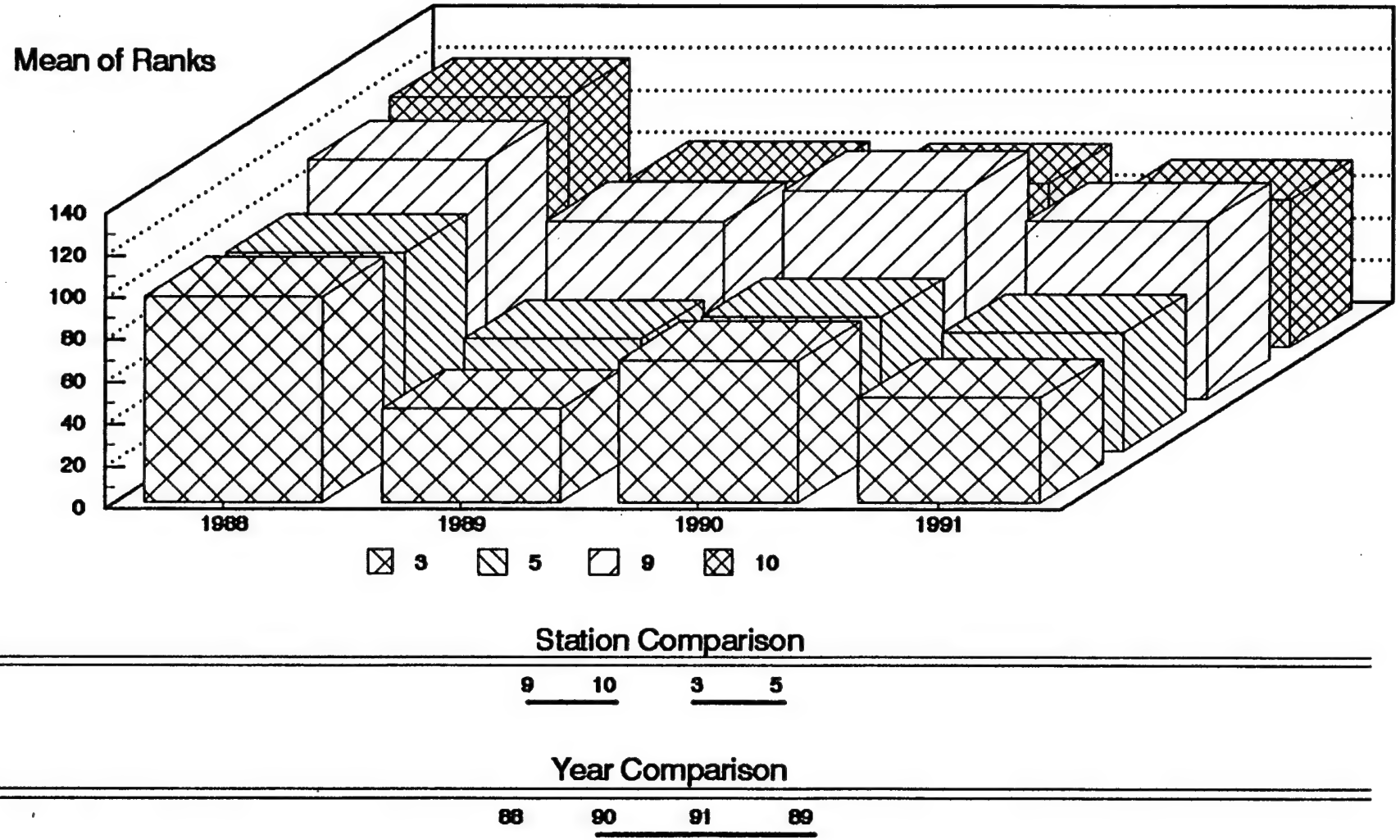


Figure 60. Graphical and statistical comparisons of the mean of ranks for juvenile steelhead abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

60). Mean catch/effort for juvenile steelhead during 1989-1991 were not significantly ($P > 0.05$) different.

Northern squawfish.- Comparisons of catch/effort for northern squawfish sampled by gill nets revealed few changes in abundance from 1988 to 1991 (Figure 61). Comparisons of catch/effort for northern squawfish at stations 3, 4 and 5 were not significantly ($P > 0.05$) different among years. Abundance at station 4 was especially interesting because in-water disposal was initiated in 1988 and it decreased from 1988 to 1991. Abundance at stations 6 and 8 varied with squawfish exhibiting significantly ($P < 0.05$) higher catch/efforts during 1991 than 1988, and 1991 and 1990 at stations 6 and 8, respectively.

We found a significant interaction in northern squawfish abundance between year and station based on comparisons of catch/effort by beach seining (Figure 62). During 1988-1991 no consistent trend in squawfish abundance occurred. Differences in catch/effort of squawfish at stations 3 and 10 were generally the highest, although significance was scattered within stations.

Comparisons of catch/effort among years within stations sampled by beach seining indicated the highest abundance of northern squawfish occurred in 1988 and 1989 at most stations (Figure 62). In 1991, catches of northern squawfish were highest at station 10 of the four years sampled. We have not observed any consistent increase in abundance of northern squawfish based on beach seine captures at any station during 1988-1991.

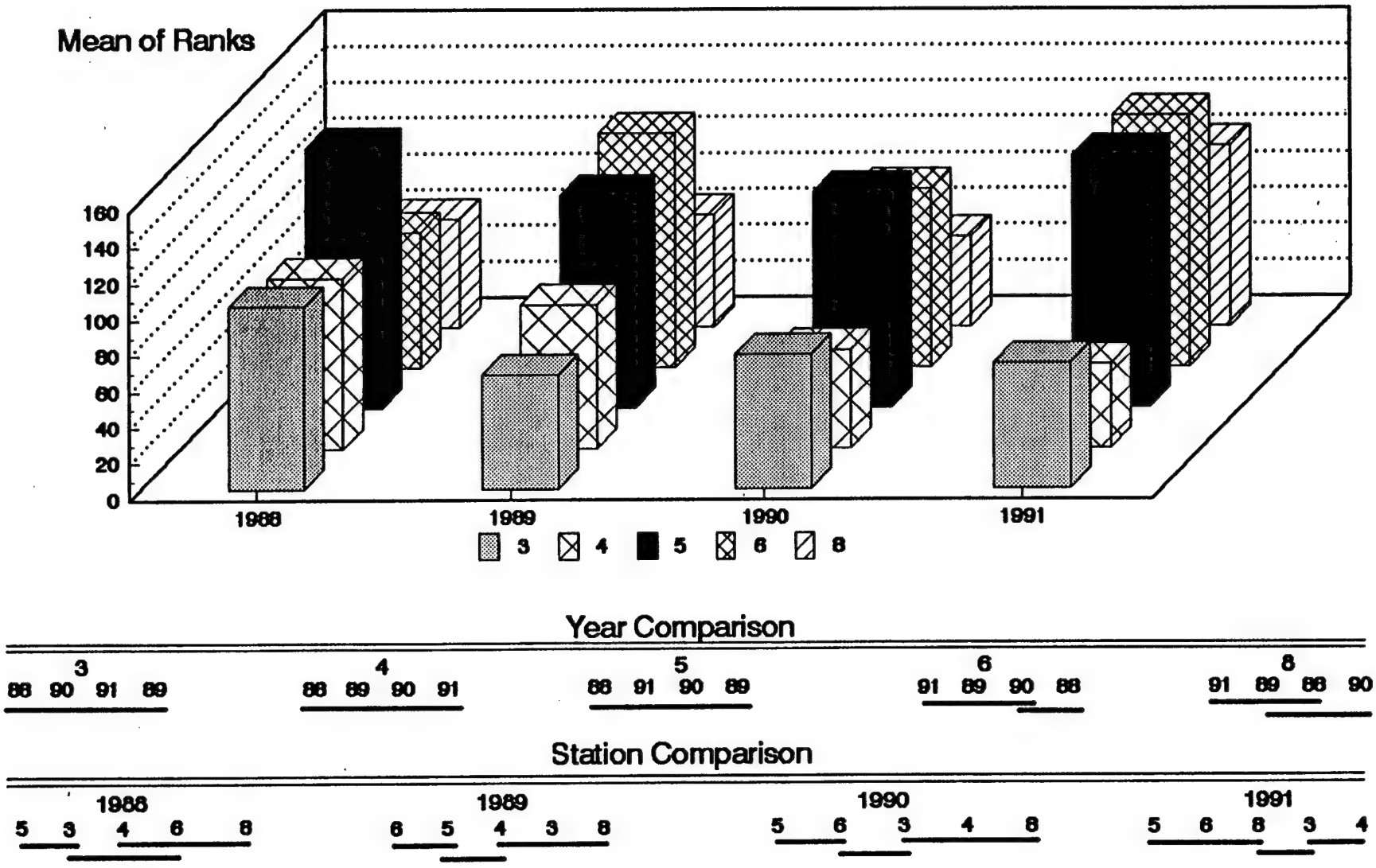
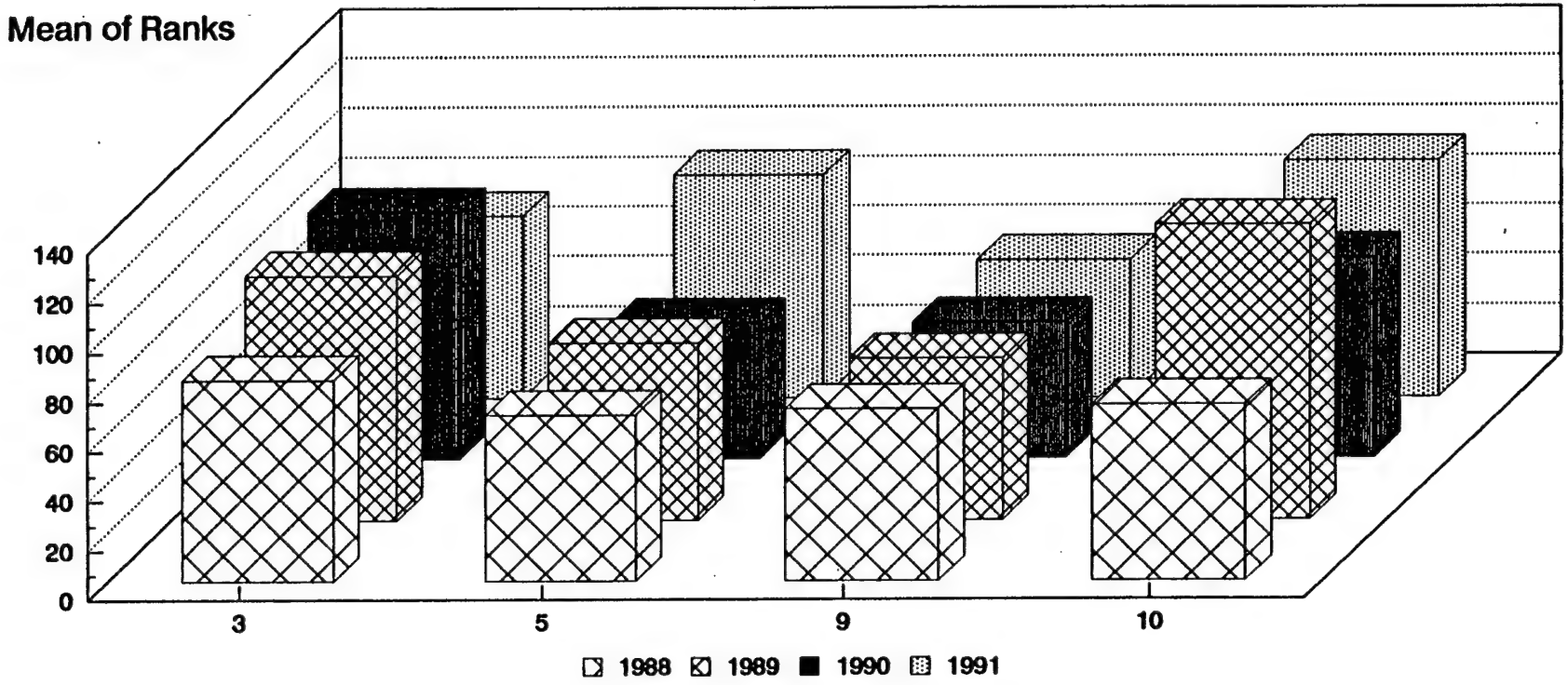


Figure 61. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).



Station Comparison

1988	1989	1990	1991
3 10 9 5	10 3 5 9	3 10 5 9	10 5 3 9

Year Comparison

3	5	9	10
90 89 88 91	91 89 88 90	88 89 90 91	89 91 90 88

Figure 62. Graphical and statistical comparisons of the mean of ranks of northern squawfish abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance (P > 0.05).

Differences in catch/effort for northern squawfish sampled by electrofishing among stations were few (Figure 63). The highest catch/efforts occurred at stations 5, 3 and 10 and these were significantly ($P < 0.05$) higher than station 9. Catch/effort data illustrates an increase in northern squawfish abundance from 1988 to 1991. Annual differences in abundance were significant ($P < 0.05$) between 1991 and 1989 and 1988, but not between 1991 and 1990.

Smallmouth bass.- The abundance of smallmouth bass based on comparisons of catch/effort during 1988 to 1991 by gill netting indicated significant ($P < 0.05$) interactions between stations and seasons (Figure 64). The abundance of smallmouth bass during spring at mid-depth disposal station 4 was not significantly ($P < 0.05$) different from 1988, the year of the first experimental disposal of dredged material in Lower Granite Reservoir. During fall, however, comparisons of catch/effort at station 4 were significantly higher in 1991 and 1988 than in 1989. Trends at the reference stations based on gill net captures generally indicate that smallmouth bass abundance has not changed through the years.

Comparisons of catch/effort for smallmouth bass by beach seining from 1988-1991 indicated the abundance of smallmouth bass was higher in downstream (RM 110) stations than in mid or upper reservoir locations (RM 127; Figure 65). Catches were highest at reference station 10 followed by reference stations 9, 3 and 5. Differences in catch/effort were significant ($P < 0.05$) between stations 10, 3 and 5 and stations 9

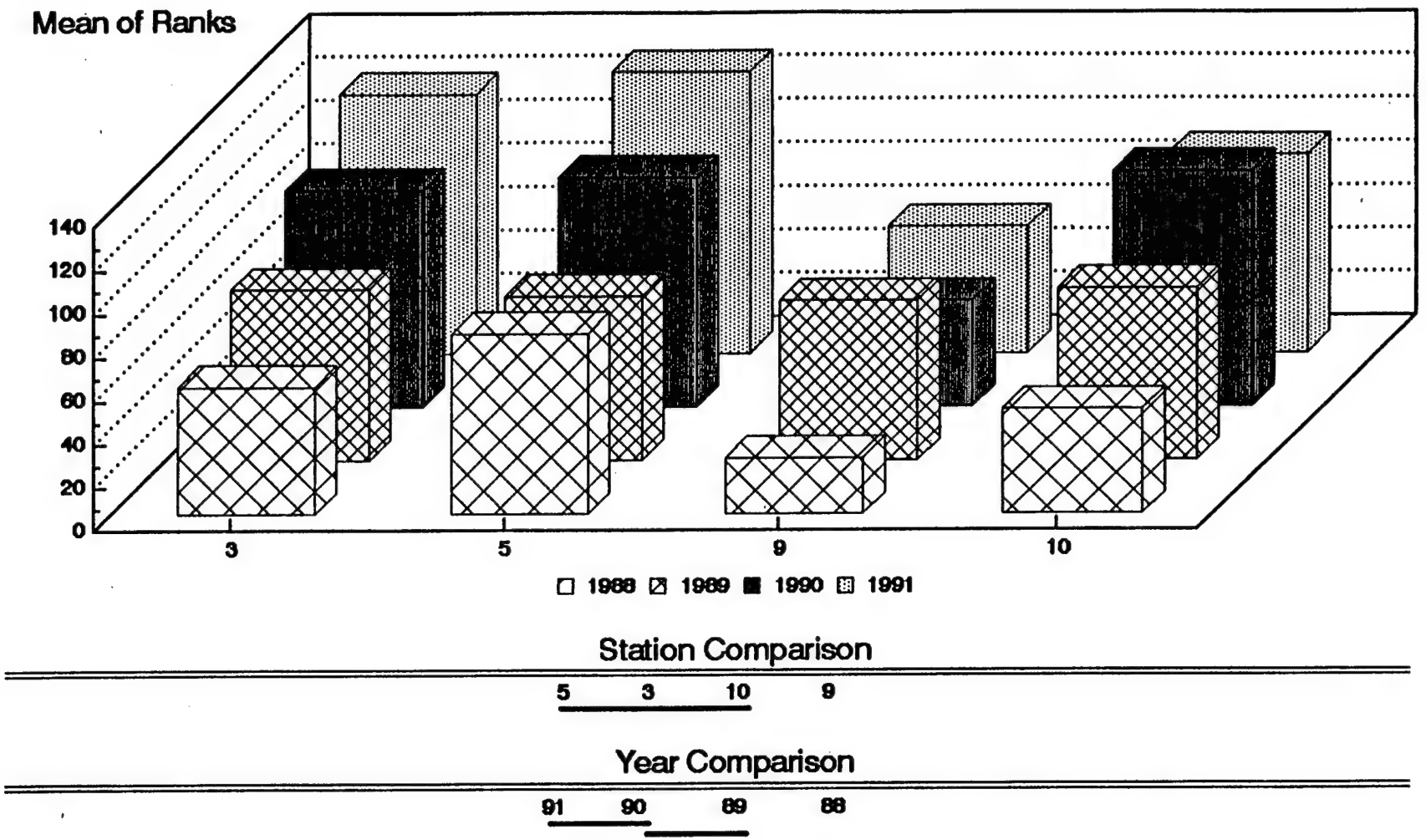
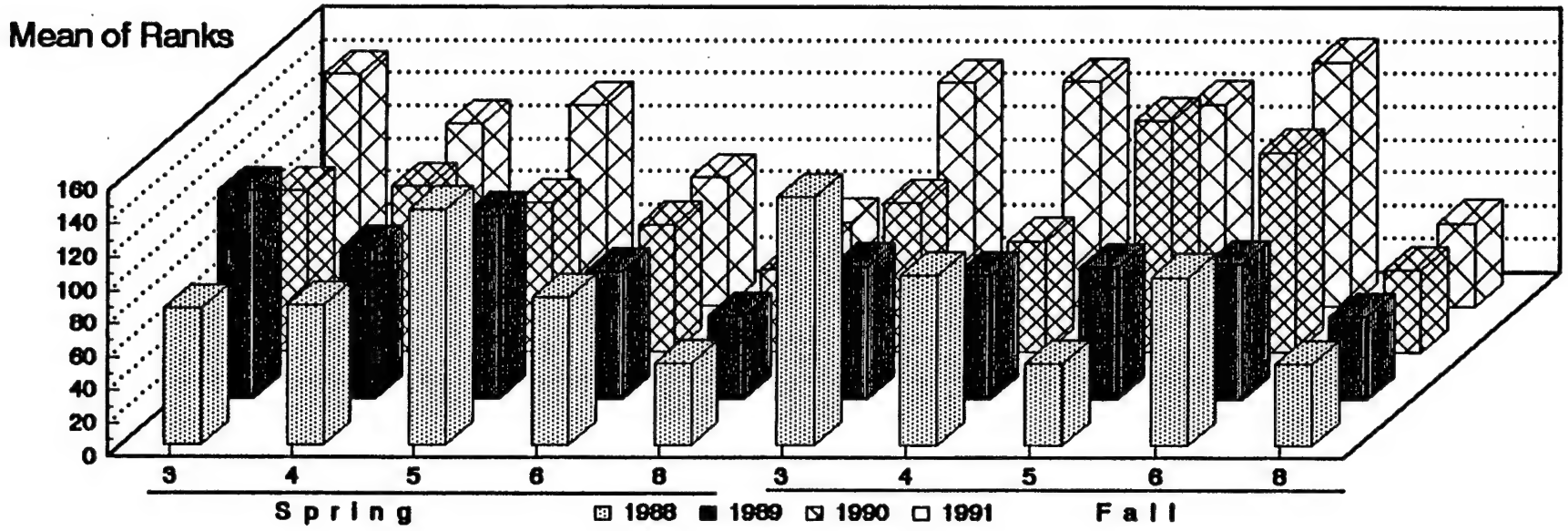


Figure 63. Graphical and statistical comparisons of the mean of ranks for northern squawfish abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).



Year Comparison

3	4	5	Spring	6	8
91 89 90 88	91 90 89 88	88 91 89 90		88 89 91 90	88 89 90 91
3	4	5	Fall	6	8
88 91 90 89	91 88 90 89	90 91 89 88		91 90 88 89	88 89 90 91

Station Comparison

1988 - Spring	1988 - Fall	1989 - Spring	1989 - Fall
5 6 4 3 8	3 4 6 5 8	3 5 4 6 8	6 3 5 4 8
1990 - Spring	1990 - Fall	1991 - Spring	1991 - Fall
4 3 5 6 8	5 6 3 4 8	3 5 4 6 8	6 3 5 4 8

Figure 64. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

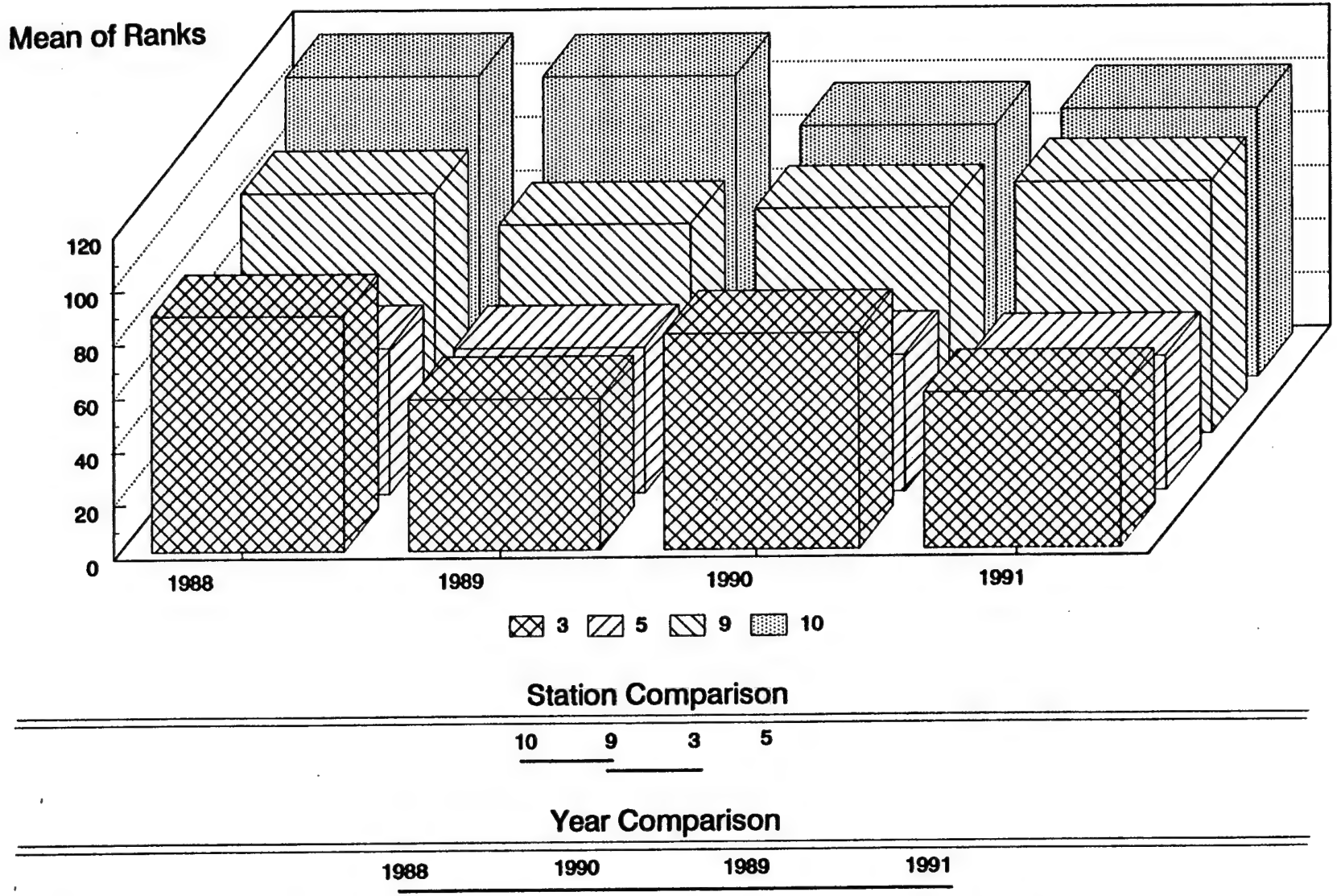


Figure 65. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

and 5. The mean of ranks of catch/effort have generally decreased since 1988, although these differences have not been significant ($P > 0.05$).

Differences in catch/effort among stations for smallmouth bass sampled by nighttime electrofishing were scattered with the highest values at reference stations 9 and 10 followed by stations 3 and 5 (Figure 66). Differences in catch/effort for smallmouth bass were significant ($P < 0.05$) between stations 9 and 3, and 10 and 5.

Annual abundance of smallmouth bass sampled by electrofishing between 1988-1991 has generally followed a similar trend as those found for northern squawfish (Figure 66). Abundance increased from 1988 to 1991 and significant ($P < 0.05$) differences in catch/effort occurred between 1991 and 1989 and 1988, but not between 1991 and 1990.

Channel catfish.- The abundance of channel catfish based on comparisons of catch/effort by gill netting has not changed during 1988-1991 (Figure 67). Comparisons of catch/effort have not changed between spring and fall at stations 3, 4, 5, 6 and 8 (Figure 68). Abundance has differed between station 8 (spring) and 5 (fall) within station and season comparisons. During 1988-1991, catch/effort at station 4 was the lowest. Seasonal differences in catch/effort were not significant during 1989, 1990 and 1991, although differences in 1988 were significant ($P < 0.05$; Figure 69). Annual comparison of catch/effort were significantly ($P < 0.050$) higher in fall 1988, although seasonal differences were not found for 1989, 1990 or 1991.

White sturgeon.- During 1988 to 1991, catch/effort of white sturgeon sampled by gill nets was highest at deep water reference

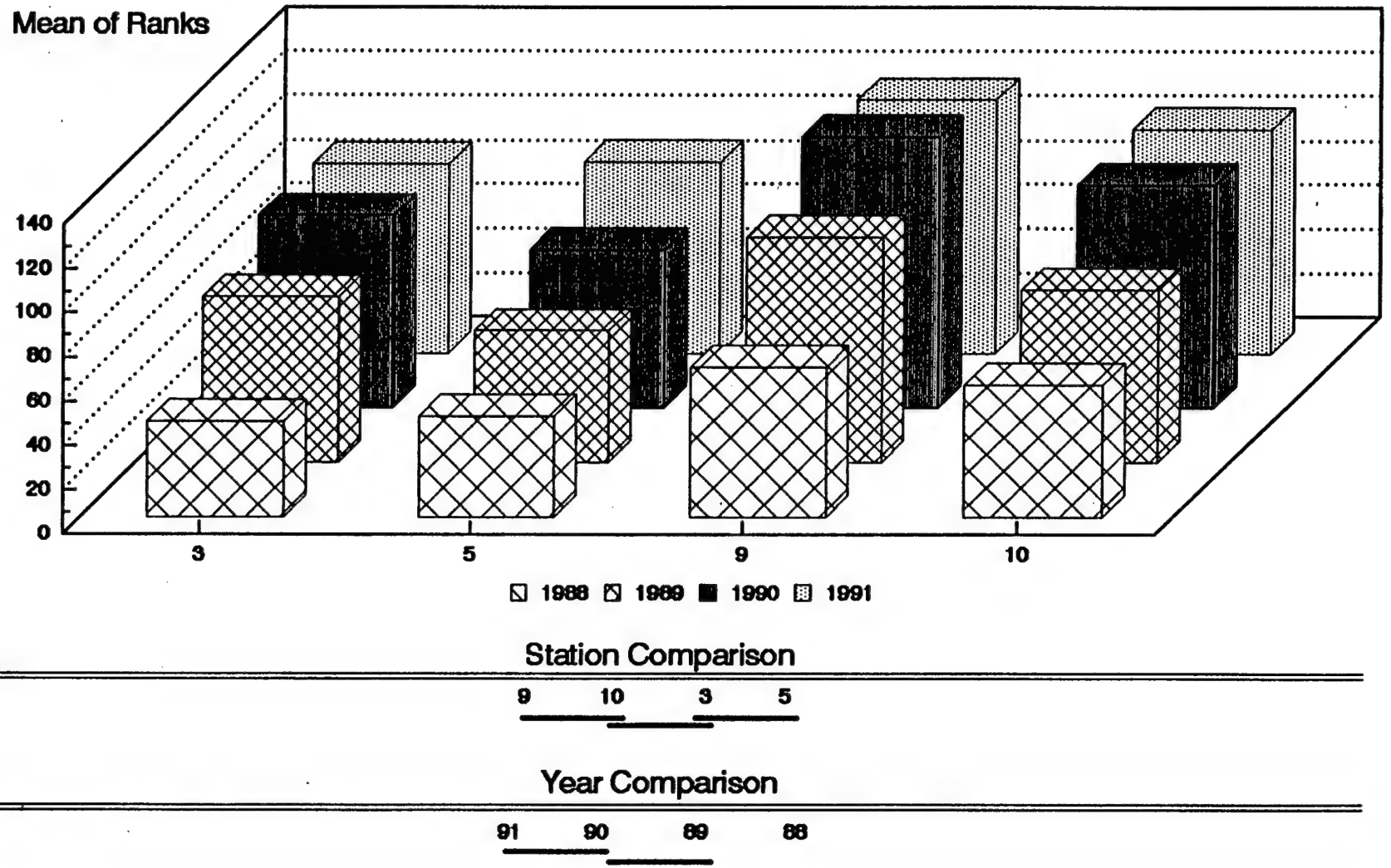


Figure 66. Graphical and statistical comparisons of the mean of ranks for smallmouth bass abundance sampled by electrofishing in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under stations and years indicate statistical nonsignificance ($P > 0.05$).

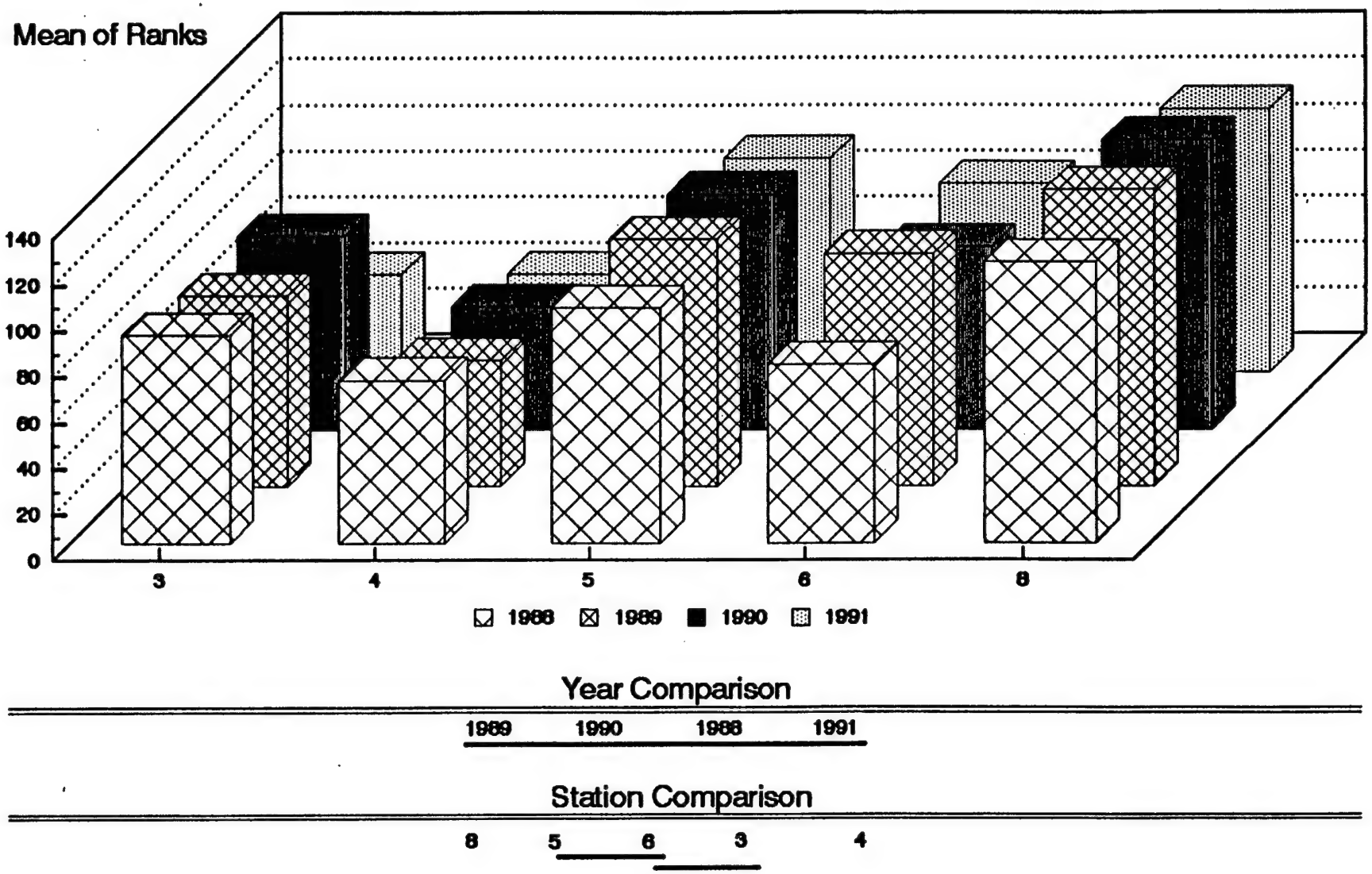


Figure 67. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

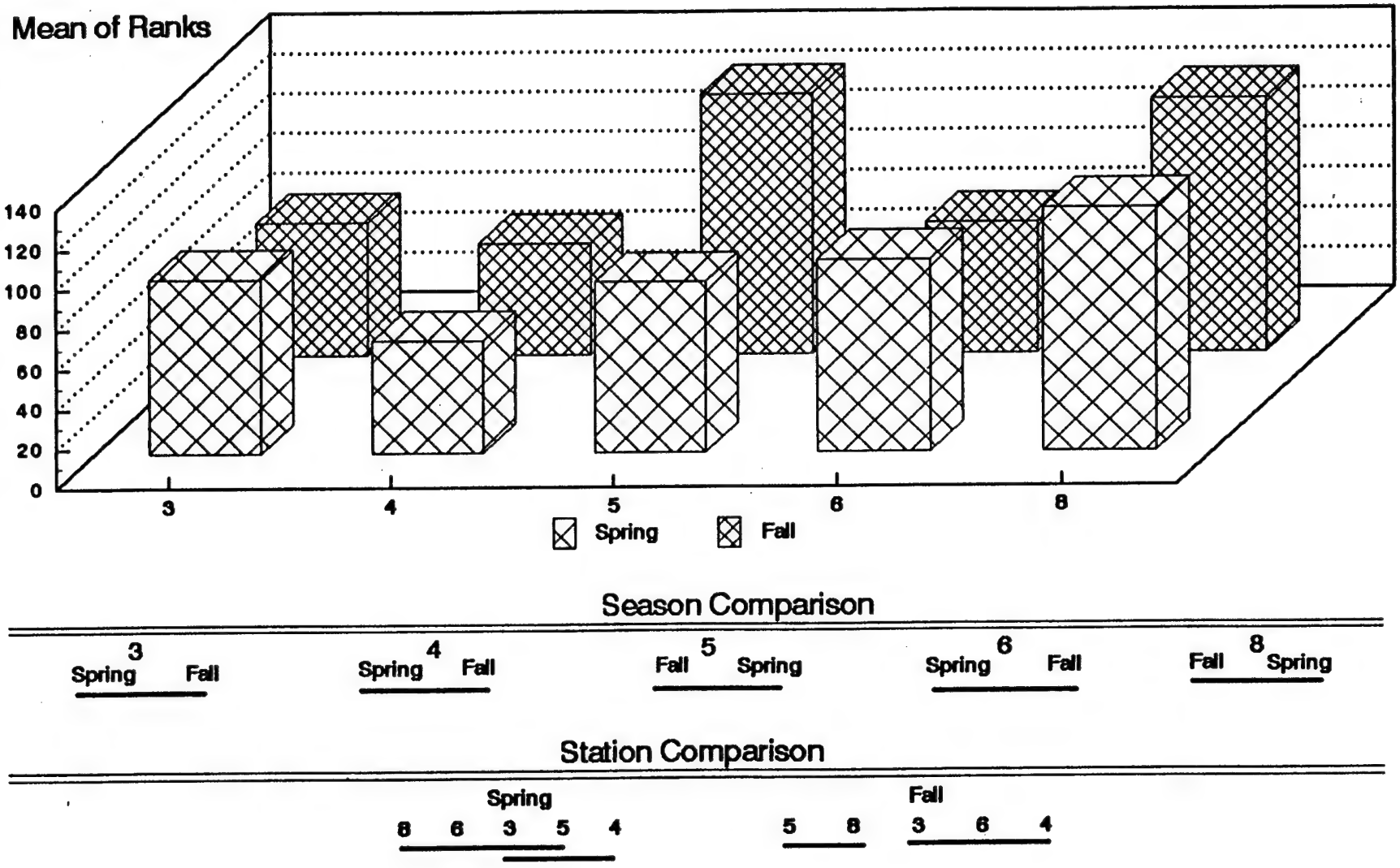


Figure 68. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under seasons and stations indicate statistical nonsignificance ($P > 0.05$).

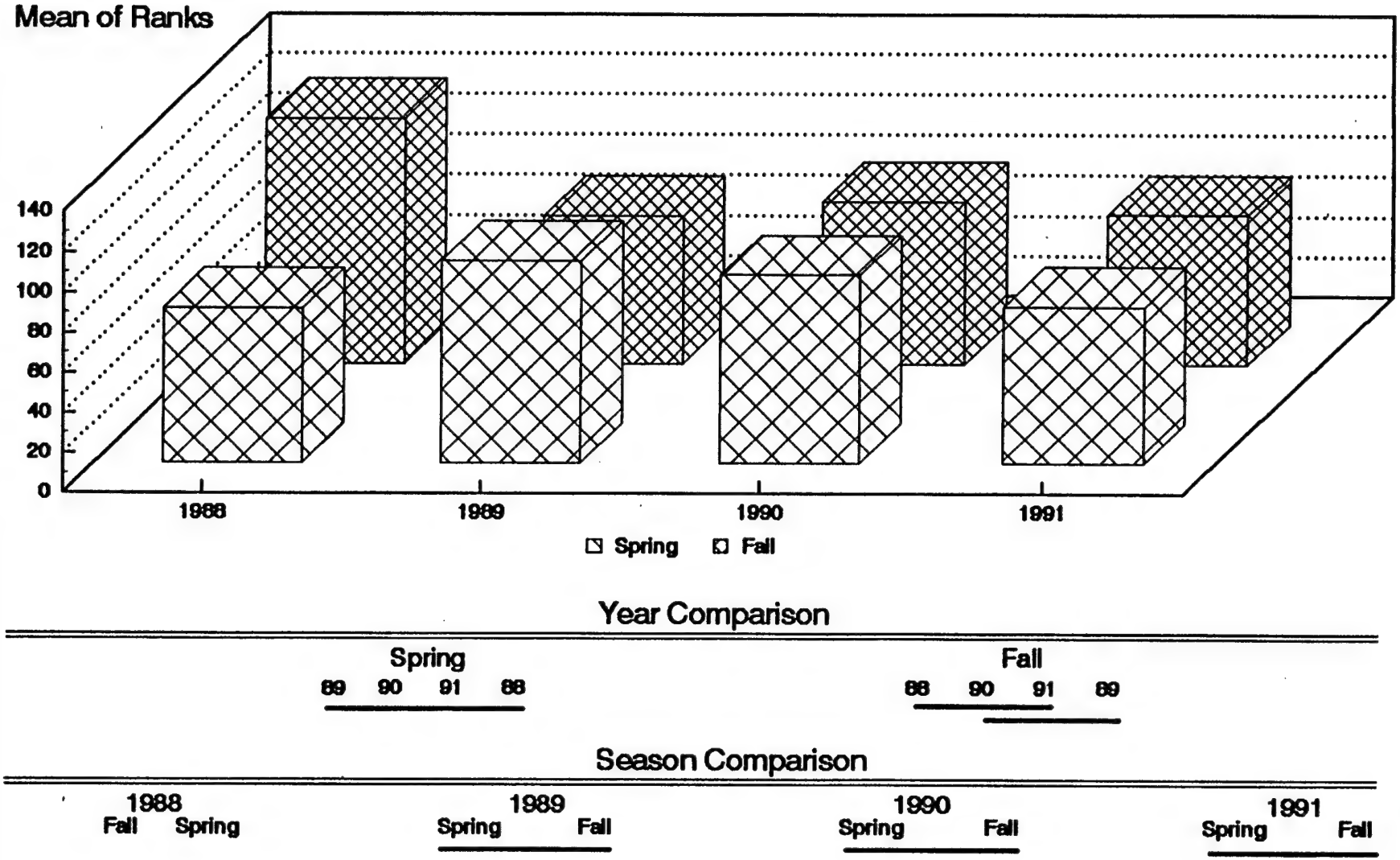


Figure 69. Graphical and statistical comparisons of the mean of ranks for channel catfish abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under years and seasons indicate statistical nonsignificance ($P > 0.05$).

station 8 and lowest at mid-depth reference station 6 (Figure 70). With the exception of 1991, catches at station 8 were significantly ($P < 0.05$) higher than other stations. Within station comparisons of abundance from 1988-1991 indicated no significant change, except at station 8 where 1991 was significantly ($P < 0.05$) lower than 1990-1988.

Larval Results

A total of 24,414 larval fish were collected by paired half-meter plankton nets and handbeam trawl during 1991 in Lower Granite Reservoir, Idaho-Washington (Table 5; Appendix Tables 1 and 2). Twelve species and two genera representing seven families were collected. Larval samples collected by handbeam trawl accounted for 83.8% ($n = 20,460$) of the total number of larval fish collected. Catostomids dominated handbeam trawl and plankton net catches during June (Figure 71), however, the highest number were collected during July (Table 5).

Relative abundance of catostomid and cyprinid fishes collected by plankton nets and handbeam trawl during July were generally similar, whereas cyprinid fishes dominated the catches during August. Five families were represented during August.

The abundance of larval predators sampled by handbeam trawl varied temporally and spatially (Figures 72 and 73). Larval smallmouth bass were collected at all stations, although the highest total numbers were collected during July at shallow water disposal station 2 (Figure 72). Catches at other stations were low. No larval smallmouth bass were collected during June.

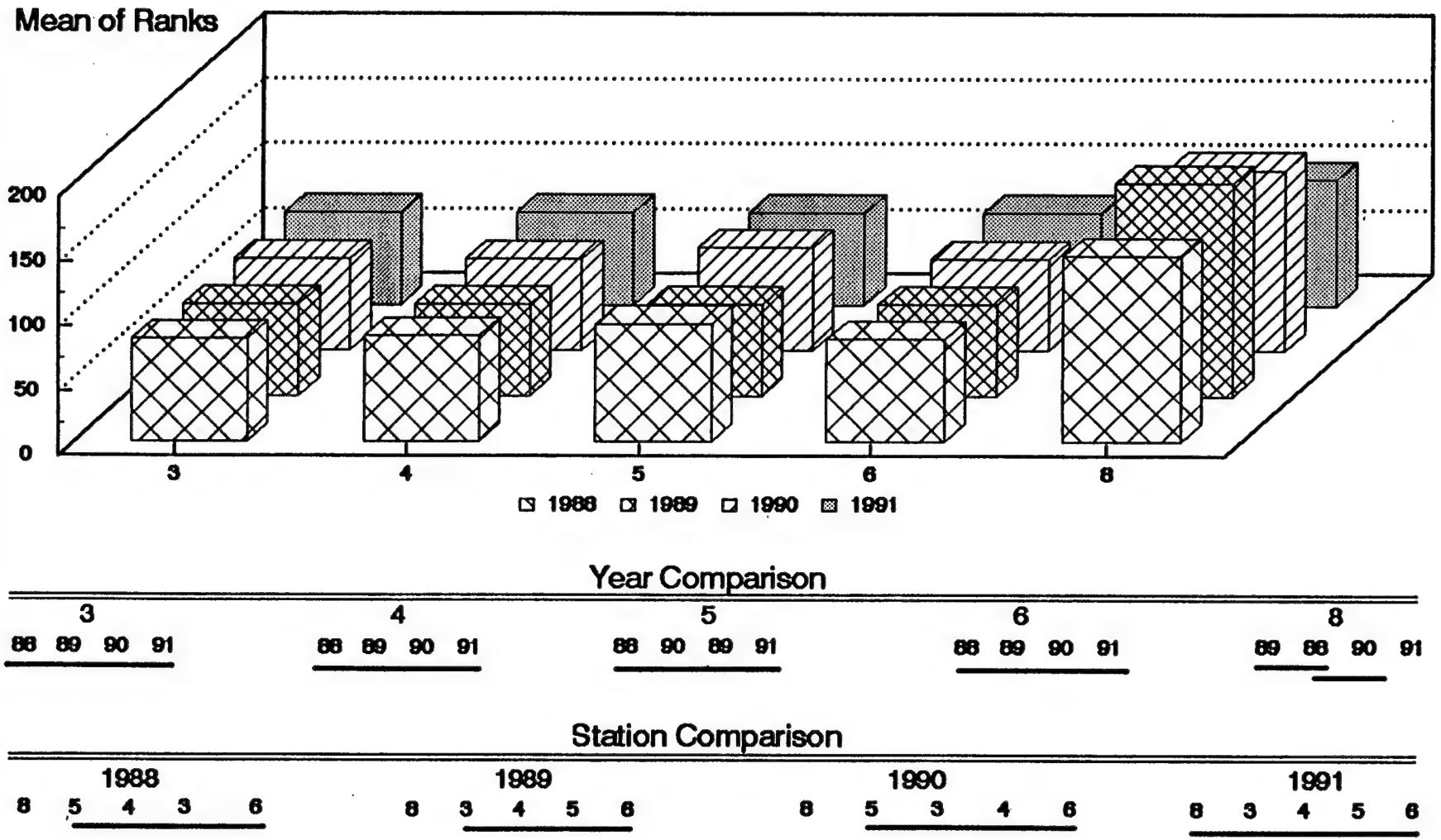


Figure 70. Graphical and statistical comparisons of the mean of ranks for white sturgeon abundance sampled by gill netting in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Horizontal lines under years and stations indicate statistical nonsignificance ($P > 0.05$).

Table 5. Larval fish collected by paired plankton nets and a handbeam trawl in Lower Granite Reservoir during 1991.

Month	June	July	August	Total
American shad		4	12	16
mountain whitefish	1			1
chiselmouth		110	18	128
carp	1		55	56
peamouth	149	308	89	546
northern squawfish	202	3,351	2,963	6,516
redside shiner		10	3	13
Cyprinid spp.		1,124	37	1,161
largescale sucker			2	2
Catostomid spp.	1,024	13,627	131	14,782
yellow bullhead			20	20
pumpkinseed		3		3
Lepomis spp.	2	260	324	586
Pomoxis spp.		85	136	221
smallmouth bass		84	17	101
Centrarchid spp.		34	177	211
yellow perch		3	1	4
unknown spp.		42	5	47
Total	1,379	19,045	3,990	24,414

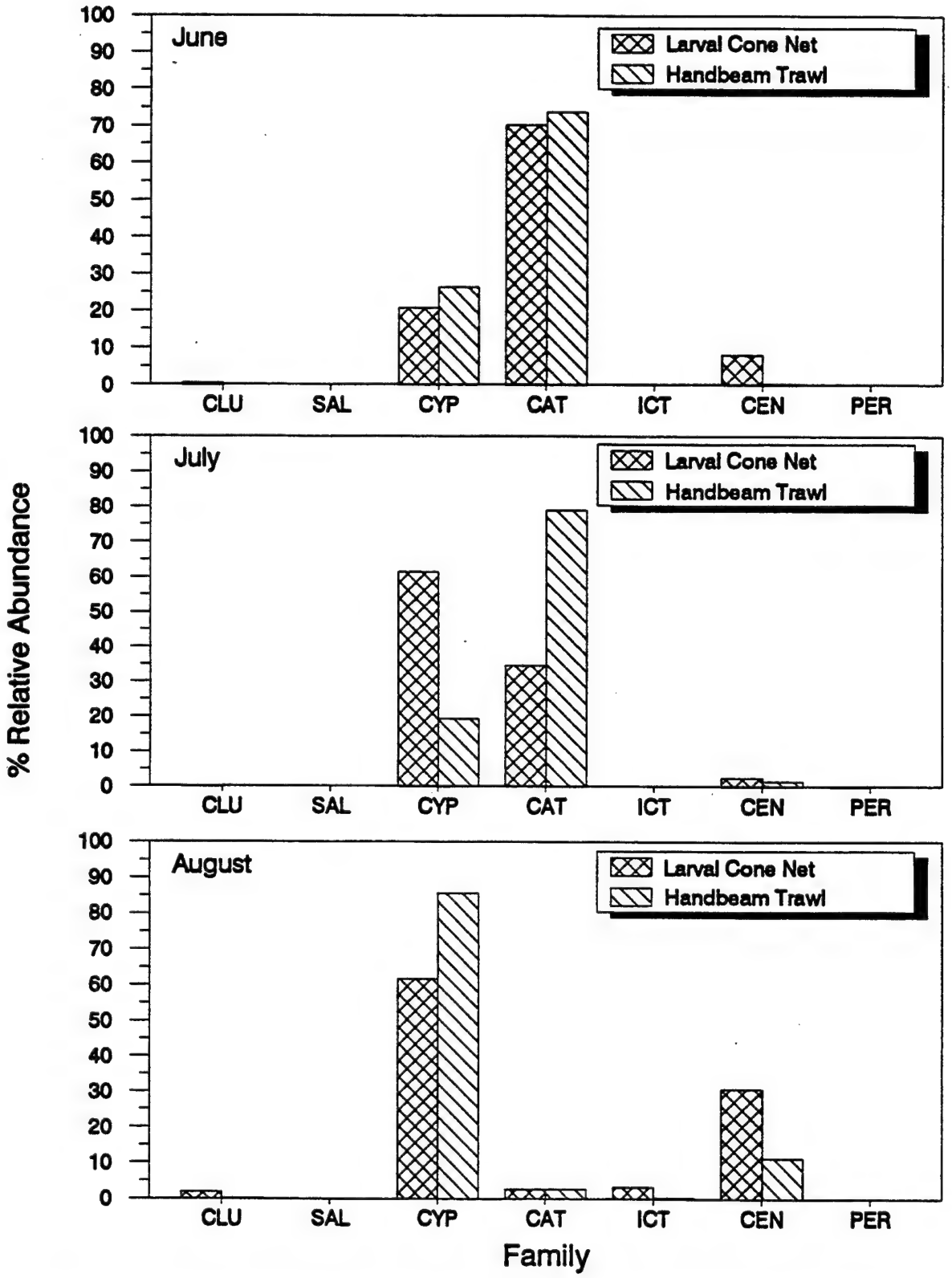


Figure 71. Larval abundance sampled by half-meter plankton nets and handbeam trawl in Lower Granite Reservoir during 1991. Family abbreviations include: CLU-Clupeidae; SAL-Salmonid; CYP-Cyprinid; CAT-Catostomid; ICT-Ictalurid; CEN-Centrarchid and PER-Percid.

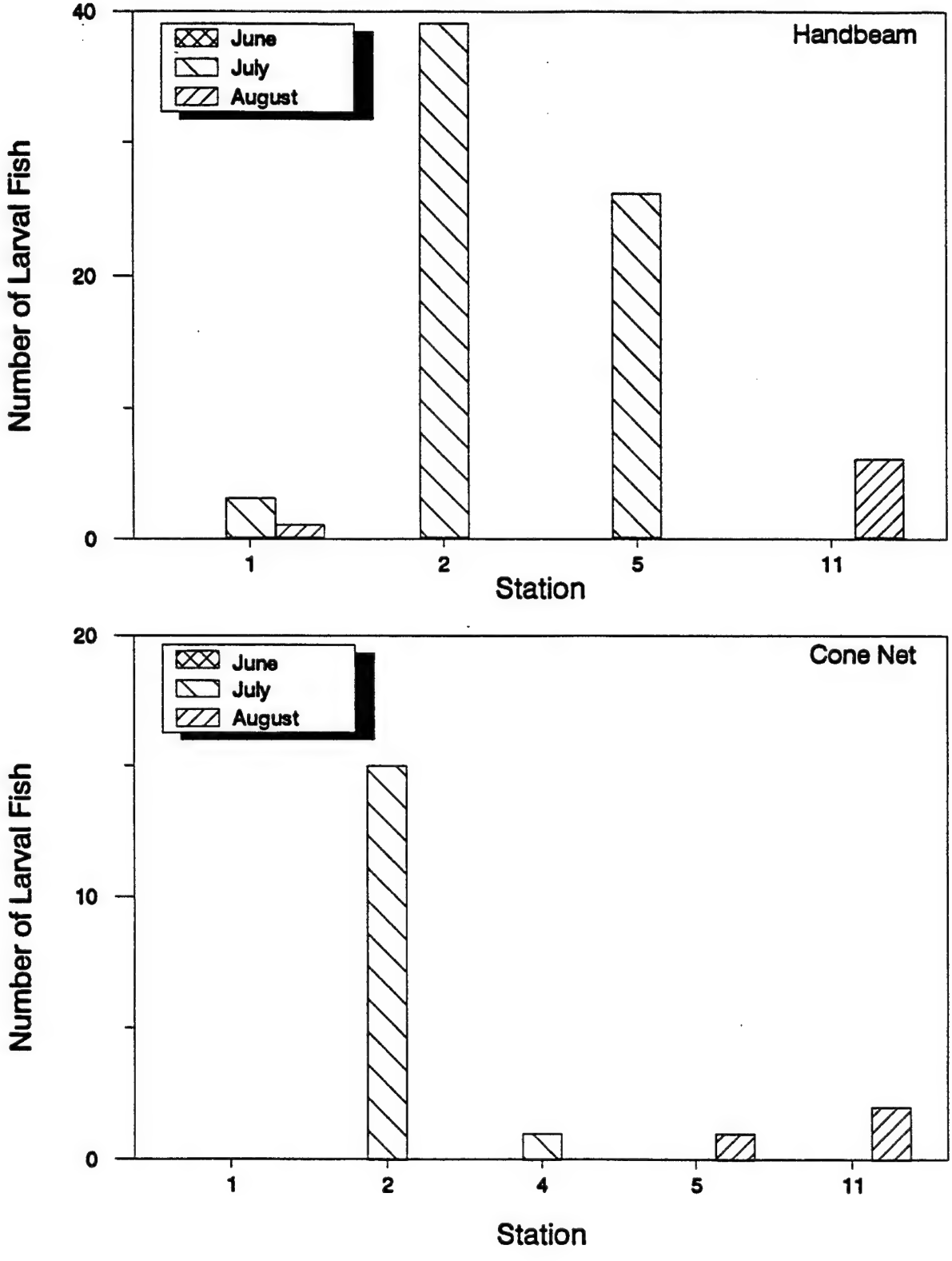


Figure 72. Larval smallmouth bass abundance sampled by half-meter plankton nets and a handbeam trawl in Lower Granite Reservoir, Idaho-Washington during 1991.

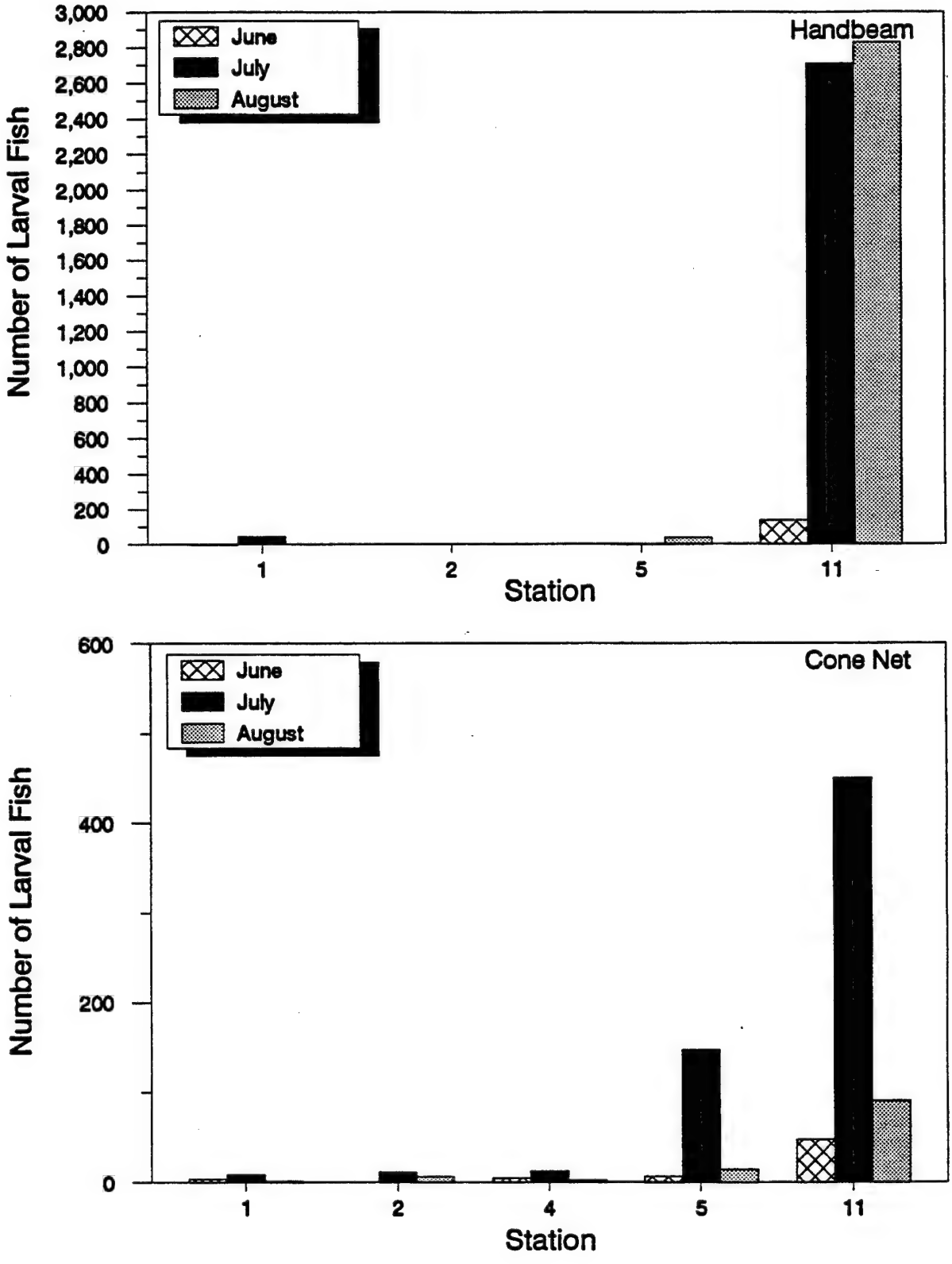


Figure 73. Larval northern squawfish abundance sampled by half-meter plankton nets and a handbeam trawl in Lower Granite Reservoir, Idaho-Washington during 1991.

Catches of larval smallmouth bass sampled by half-meter plankton nets were low and similar at stations 4, 5 and 11 (Figure 72). Disposal station 2 had the highest number collected, and no larval smallmouth bass were collected at disposal station 1. No smallmouth bass were collected by plankton nets during June.

Larval northern squawfish were collected at all stations with the exception of shallow water disposal station 2 (Figure 73). Catches of squawfish at shallow water disposal station 1 and reference station 5 were low and similar, as they were sampled once at station 1 during July and once at station 5 during August. The highest total number of larval squawfish were sampled at shallow water reference station 11. Larval squawfish were sampled at station 11 during June, July and August with the highest number collected in August followed closely by July.

Larval northern squawfish were sampled in pelagic waters from mid-June through mid-August by half-meter plankton nets (Figure 73). Larval squawfish abundance was highest at shallow water reference station 11, followed by shallow water reference station 5. Catches were low and similar at shallow water (1 and 2) and mid-depth (4) disposal stations.

DISCUSSION

Results of our fish sampling have indicated that the species composition and relative abundance of fishes in Lower Granite Reservoir has changed little since we started sampling in 1985 (Bennett and Shrier 1986). During spring 1991 (Table 2), the more abundant species in rank order include largescale sucker, smallmouth bass, northern squawfish,

chiselmouth and pumpkinseed whereas in 1985 redside shiner, northern squawfish, largescale sucker, chiselmouth and peamouth were the dominant resident species. Differences in abundance seem primarily related to the increased abundance of centrarchid fishes (smallmouth bass and pumpkinseed) and decreased abundance of redside shiners. Northern squawfish have remained about at the same level of abundance. During summer 1991, our collections were limited to shoreline sampling, whereas in 1985 a significant amount of effort was conducted by gill netting in pelagic waters. In the fall of both years, largescale sucker dominated our catches (Table 4) followed by smallmouth bass. Northern squawfish were third in abundance in 1985 (Bennett and Shrier 1986) and fourth in rank abundance in 1991. The abundance of redside shiners and peamouths in 1991 compared to 1985 indicate a recent decrease in abundance in Lower Granite Reservoir during the fall sampling season. Based on this comparison, we have not seen an overall change in the fish community structure in Lower Granite during this 7 year period.

We have continued to monitor the abundance of predators in the reservoir because of concern for the increase in their abundance. If a major change in abundance were occurring as a result of the disposal in Lower Granite Reservoir, we should see evidence after 1989. Channel catfish, which are at a comparatively low level of abundance in Lower Granite Reservoir compared to Little Goose Reservoir (Bennett et al. 1983), have generally declined (Figure 53) since 1989. Their highest abundance is at reference stations 8, 5 and 6 based on our sampling from 1989-1991.

Collections of northern squawfish have to be compared within gear types. For example, other than occasionally in the spring, predator-sized squawfish are collected primarily by gill netting. Their abundance, based on a statistical comparison of catch/effort, was not significantly ($P > 0.05$) higher in 1991 than 1989 (Figure 46). Differences in catch/effort by beach seining, a technique that samples primarily age-0 and age-1 fish, have again indicated that squawfish abundance has not changed over a 3 year period (Figure 47). Catch/effort by electrofishing, a technique that samples a range of size classes especially in the spring, was significantly ($P < 0.05$) higher in 1991 than 1989 (Figure 48). These differences are difficult to attribute to the dredge disposal stations as catch/effort was statistically similar among reference stations 5, 3 and 10 and disposal station 1.

Smallmouth bass is one species that has probably increased in abundance in the last few years in Lower Granite Reservoir. As indicated earlier, the number of smallmouth bass collected has increased since 1985, although the increase in numbers collected may be related to increased gear efficiency. Probably the least size selective and efficient collecting method for smallmouth is electrofishing (Arthaud 1992) and results indicate an overall increase in catch/effort from 1989 to 1991 (Figure 52). In 1985 we used a noncommercially assembled electrofishing boat, whereas since 1990 we have used a Smith-Root electrofishing boat. Our ability to stun smallmouth bass in deeper waters and further from the boat is one highly apparent difference that

would account for increased efficiency due to better equipment. Gill nets are not highly effective for smallmouth bass sampling, especially when water clarity is high, however our data also indicate an increase in catch/effort from 1989 to 1991 (Figure 49). Results from beach seining, a technique that samples primarily age-0 bass, suggest smallmouth bass abundance has changed little from 1989 (Figure 51).

Biologically, conditions in Lower Granite Reservoir have been more favorable for enhanced recruitment with more stable water levels with initiation of minimum operating pool. Water level fluctuations in Little Goose Reservoir, similar in magnitude to those in Lower Granite Reservoir, were shown by Bratovich (1985) to adversely affect bass recruitment. Water level fluctuations in Lower Granite Reservoir have been more stable in recent years and may account for the apparent increase in smallmouth bass abundance. Results from 1992 sampling will be especially interesting because the 1991 spring water levels were highly stable as a result of an operating regimen at minimum operating pool throughout the spawning and incubation period.

We have some evidence of year-class strength in 1991 from our larval fish collections. Larval smallmouth bass were collected in highest abundance at disposal station 2 and reference station 5 (Figure 72). Expanded numbers of larval smallmouth bass collected indicate relatively low abundance in pelagic waters while shoreline collections indicated higher abundance (Appendix Tables 1 and 2). Numbers collected in 1991 were similar to those collected in other years, although few of

the stations sampled could be classified as highly productive smallmouth bass spawning and rearing areas.

Abundance of larval northern squawfish was about two times higher in both pelagic and littoral areas compared to smallmouth bass abundance. Larval collections of northern squawfish indicated a wider range of stations used for rearing, although the highest numbers were ostensibly at reference station 11 near Port of Wilma. The highest abundance of larval northern squawfish has been consistently at reference station 11 (Bennett et al. 1993). Larval squawfish were collected for 3 weekly sampling periods at disposal station 1 using a hand beam trawl that sampled along the immediate shoreline habitat. Pelagically, the distribution of larval northern squawfish was more ubiquitous within the reservoir, although expanded densities were consistently low at disposal stations 1, 2, and 4.

Objective 2. To assess white sturgeon abundance and habitat factors associated with their abundance in Lower Granite Reservoir;

METHODS

The spring through fall period was divided into two intervals from 1 April to 7 July (spring-summer) and 2 August to 15 November, 1991 (fall-winter) for sampling white sturgeon. A total of 10 gill net and five setline passes were conducted during the sampling period.

Gill nets were the primary gear used to capture and assess relative sturgeon abundance. Eight experimental gill nets (1.8 x 61.2 m; 5.9 x 200.7 ft) were set on the reservoir bottom perpendicular to the shoreline at each of the nine transects. Four nets with bar mesh ranging from 2.54-15 cm (1 x 5.9 in) were fished at the deepest cross section of the main channel with the remaining four nets fished adjacent to the main channel, typically on bench areas. Gill nets were fished for a total of 6 hours and checked at 3 hour intervals.

Setline sampling was conducted at each transect to supplement gill net effort and reduce potential gear bias. Additional random locations were later sampled to increase setline efforts. Setlines were fished for approximately 72 hours per transect and rebaited at 24-48 hour intervals. Setline sampling consisted of a 122 m (400 ft) mainline (0.25 inch cord rope) weighted on the bottom with tuna circle hooks attached every 3 m (9.8 ft) for a total of 24 hooks. Gangen lines were constructed with a stainless steel halibut snap and 4/0 ball bearing swivel attached to 100-250 kg test gangen twine. A stainless steel hog ring crimped onto a cadmium-tin, coated, circle tuna hook was tied to each gangen line with hooks ranging in size from 16/0, 14/0 and 12/0.

Each gangen line measured approximately 60 cm (23.6 in) from mainline to hook and were rigged onto the mainline in random order. Hooks were primarily baited with Pacific lamprey *Entosphenus tridentatus* and largescale suckers. A 61 m (200 ft) foam-filled rope coupled with an ultrasonic transmitter was attached and submerged with the mainline to facilitate locating the line to prevent theft and navigation hazards. Setlines were retrieved by locating the sonic transmitter and intercepting the submerged float line with a grapple hook.

Captured sturgeon were measured, weighed, marked and released. Sturgeon were marked with a passive integrated transponder (P.I.T.) injected into the dorsal musculature midway between the leading edge of the dorsal fin and right lateral row of scutes. An external numbered aluminum lap seal tag was also crimped around the leading right pectoral fin ray for ease of identification.

Surface and bottom velocity, water depth, dissolved oxygen and temperature were measured at all locations sampled for sturgeon. Water velocities, temperature and dissolved oxygen were periodically recorded throughout the reservoir during sampling to provide comparative data among stations. Swoffer digital current and YSI Model 54 meters were used to measure velocity, temperature and dissolved oxygen. Water depth was recorded with a Lowrance Mach 1 Eagle echosounding chart recorder.

A Jolly-Seber open population estimator and 95% confidence intervals were used to determine population abundance. A high number of multiple recaptures required for the Jolly-Seber program limited

application until completion of sampling. A modified Schnabel multi-census estimator was computed for comparison.

RESULTS

Approximately 4,267 gill net and 6,206 setline hours of effort were expended to capture 545 white sturgeon in Lower Granite Reservoir from 1 April to 15 November, 1991. A total of 518 sturgeon were collected with gill nets and 27 fish by setlines.

Approximately 57% of all sturgeon (n = 257) collected were located between the Port of Wilma at RM 133.7 and RM 137.1. These locations coincide with the highest catch rates (0.43 sturgeon/6 h). Catch rates declined at mid and lower reservoir transects (Figures 74 and 75).

Catch rates by gill nets were significantly higher at sampling locations above RM 129.2 ($P < 0.05$) than lower reservoir transects, except at RM 116.5 (Figure 76). Gill net catch rates at RM 116.5 were equivalent to upper reservoir locations during April through July, but declined substantially during the latter sampling interval. Number of sturgeon sampled per transect with gill nets were similar between April-July and August-November intervals. Catch rates by gill nets were significantly ($P < 0.05$) different between sampling intervals at RM 116.5 and RM 133.7 (Figure 77).

Population abundance of sturgeon > 45 cm total length in Lower Granite Reservoir was estimated by Jolly-Seber at 1,372 individuals with a 95% confidence interval from 578 to 2,166. A modified Schnabel

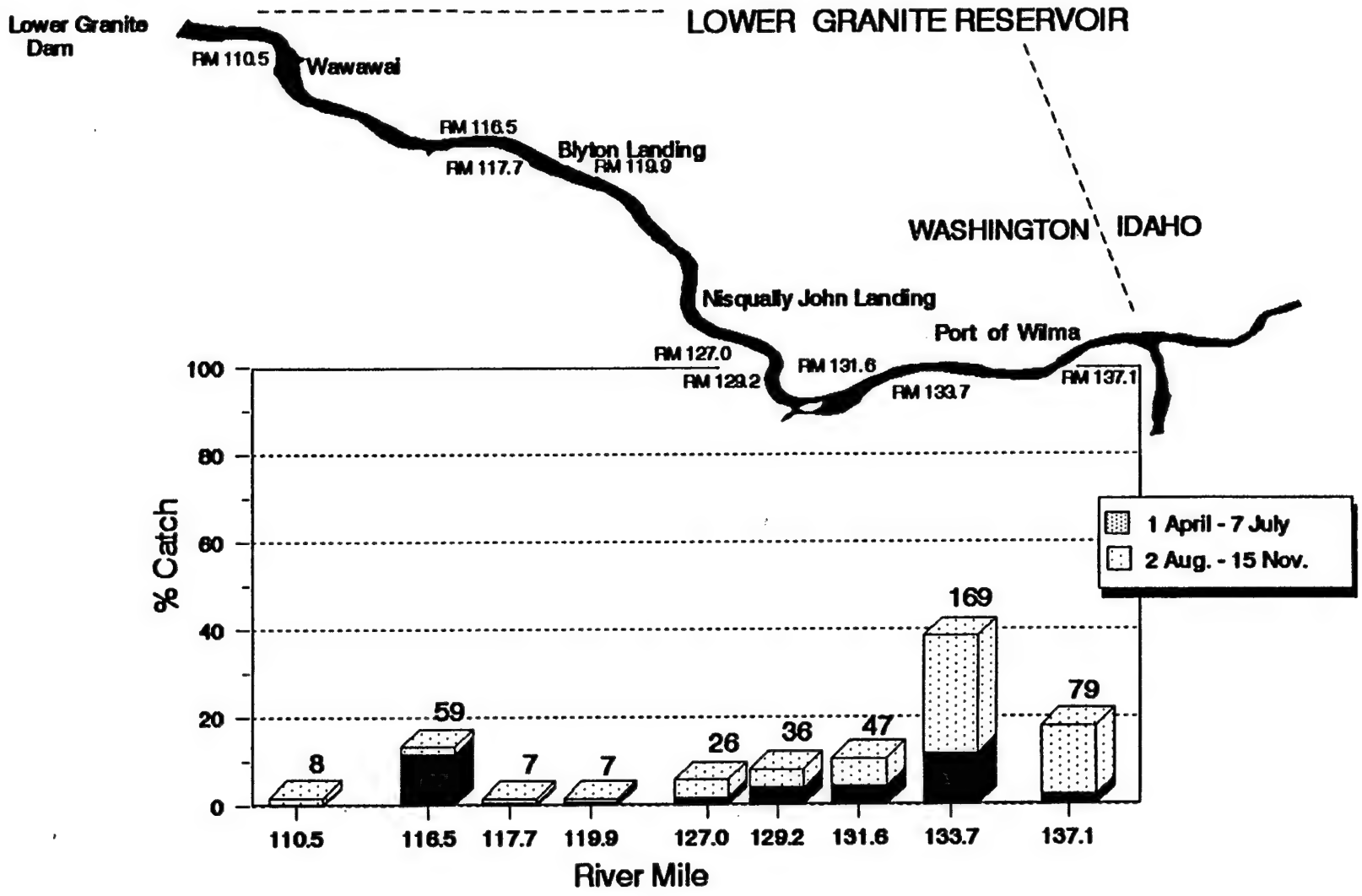


Figure 74. Percent catch of white sturgeon sampled by gill nets and setlines in Lower Granite Reservoir, Idaho-Washington during 1 April to 15 November, 1991.

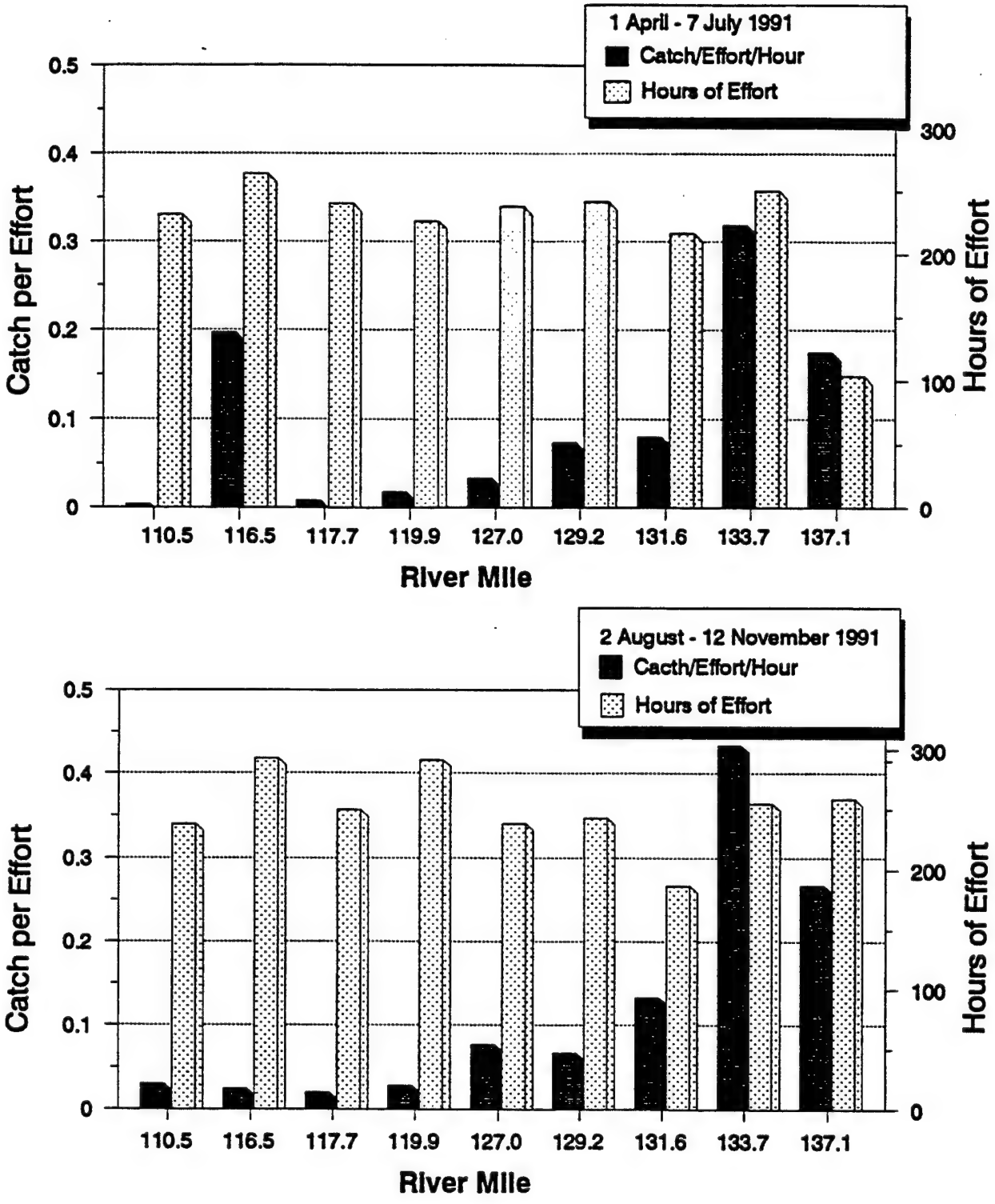


Figure 75. Catch/effort for white sturgeon captured by gill nets in Lower Granite Reservoir, Idaho-Washington during 1 April to 12 November, 1991.

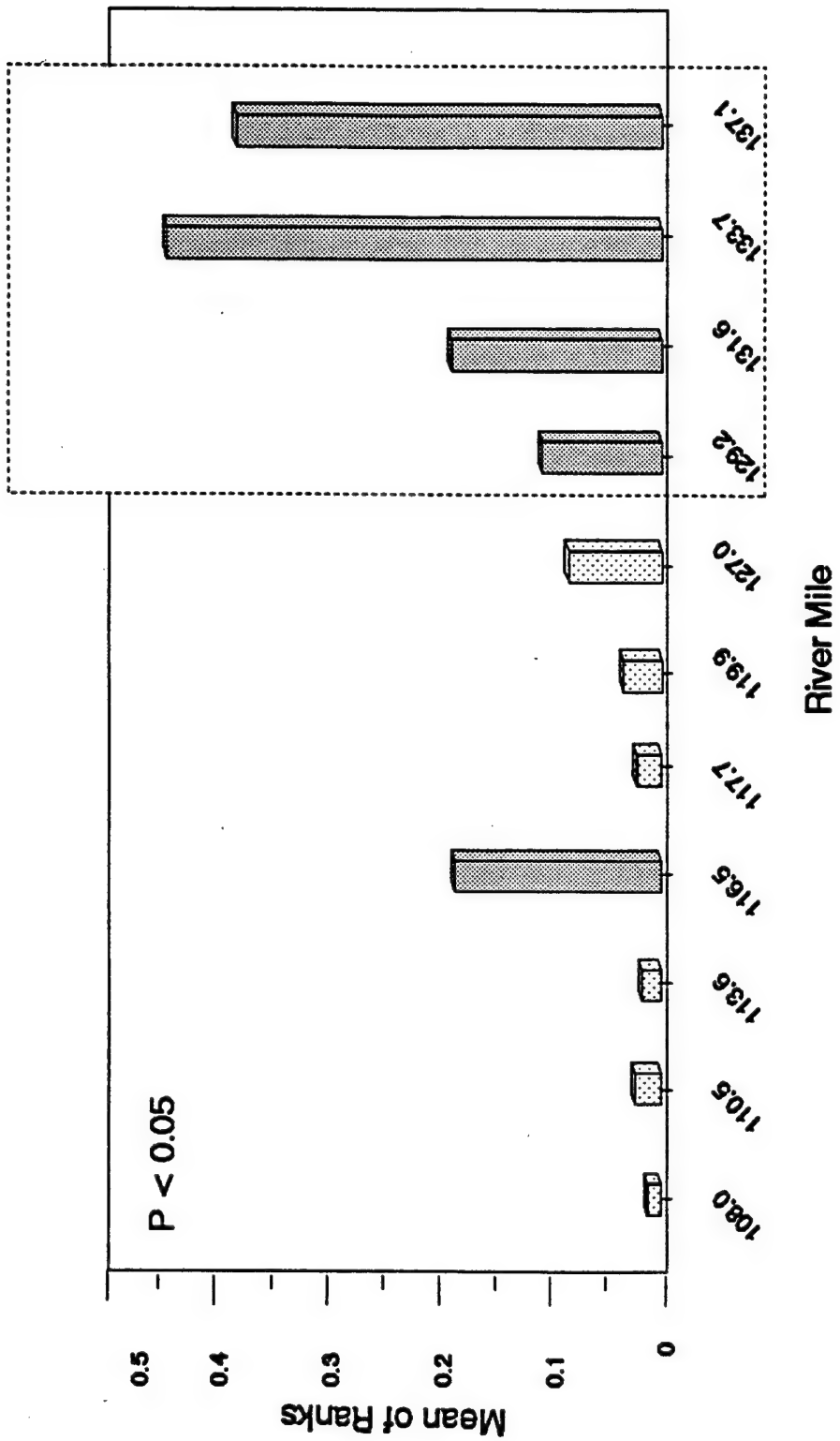
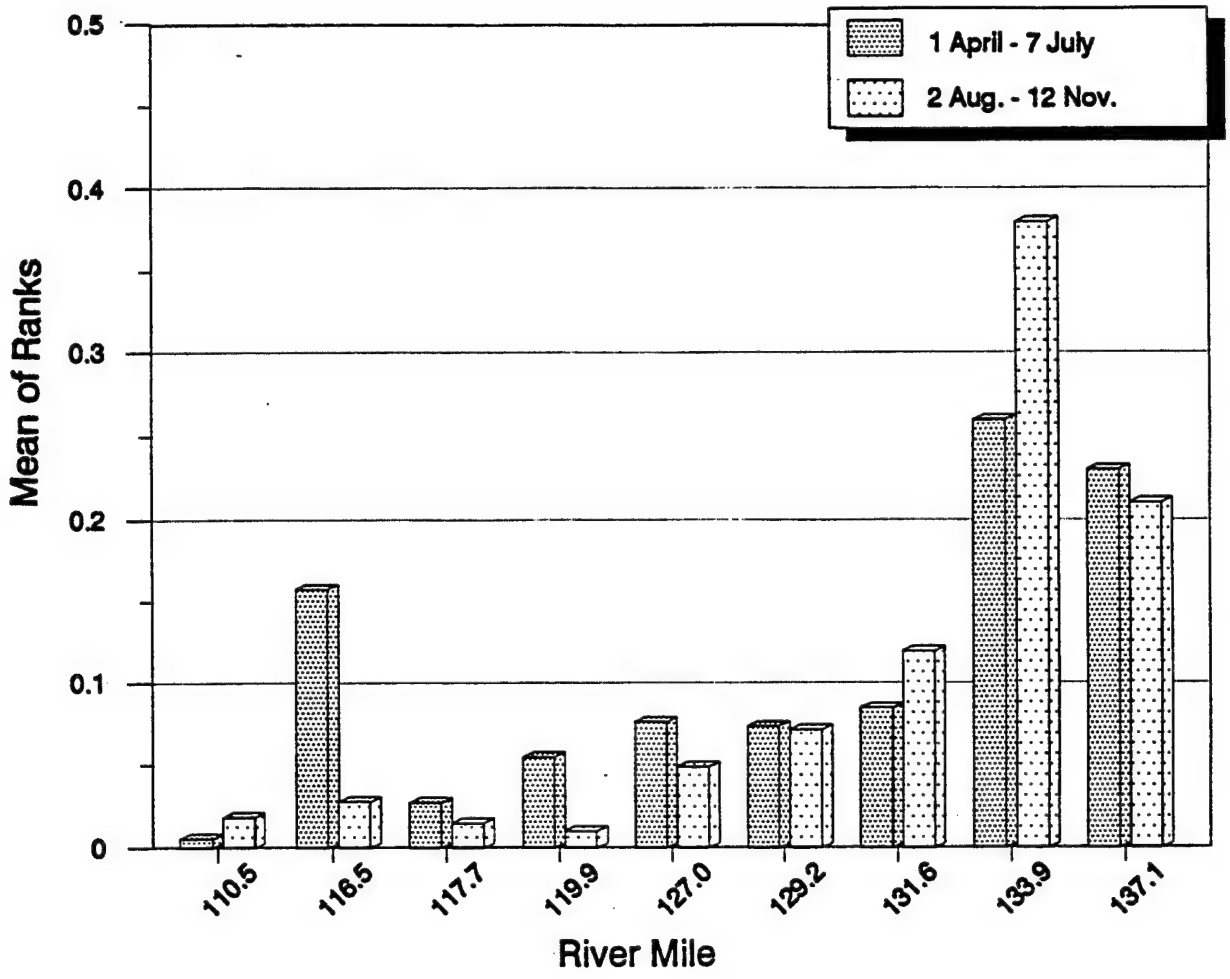


Figure 76. Comparison of white sturgeon catches between sample locations in Lower Granite Reservoir, Idaho-Washington during 1991. Shaded bars indicate statistical nonsignificance ($P > 0.05$).



Sample Interval Comparison within Location

	110.5	116.5	117.7	119.9	127.0	129.2	131.6	133.9	137.1
01 APR-07 JUL 02 AUG-12 NOV	|		|	|	|	|	|		|

Figure 77. Comparison of white sturgeon catches between April-July and August-November within sample locations in Lower Granite Reservoir, Idaho-Washington during 1991. Sample intervals joined by a vertical line indicate statistical nonsignificance ($P > 0.05$).

estimator yielded similar results with 1,524 individuals and a 95% confidence interval of 1,155 to 2,240.

Total lengths of sturgeon sampled ranged from 12.1-265 cm with a mean of 79.4 cm tail length (TL) for gill nets and 142.5 cm TL for setlines. Approximately 93% of the sturgeon sampled were < 122 cm while 2% were > 168 cm (Figure 78). Seven sturgeon ranging from 12.1-17.0 cm TL were collected during August-September at RM 133.7 and RM 137.1.

A total of 105 white sturgeon were recaptured from 2 April to 15 November, 1991. Net movement of sturgeon initially marked and recaptured in 1991 ranged from 0.0-21.1 river miles with seven fish travelling > 15 river miles since their last recorded capture. Sturgeon sampled during the study interval travelled a mean distance of 11.2 river miles upstream and 5.9 river miles downstream (Tables 6 and 7).

Depth of main channel areas sampled between RM 110.5 and RM 137.1 ranged from 14-36 m (46-118 ft) with adjacent bench areas typically ranging from 9-13 m (29.5-42.6 ft) deep. Sturgeon were collected at depths ranging from 4-36 m (13.1-118 ft) with a mean depth of 19 m (62.3 ft; Figure 79). White sturgeon captures were significantly higher ($P < 0.05$) in main channel areas between RM 129.2 and RM 137.1 (Figure 80) than on bench areas, as 57 sturgeon were sampled on bench areas adjacent to the main channel. No sturgeon were collected on bench areas with setlines. Sturgeon > 40 cm were sampled throughout the reservoir, while fish < 40 cm were typically captured at upper reservoir locations in depths < 20 m (65.6 ft).

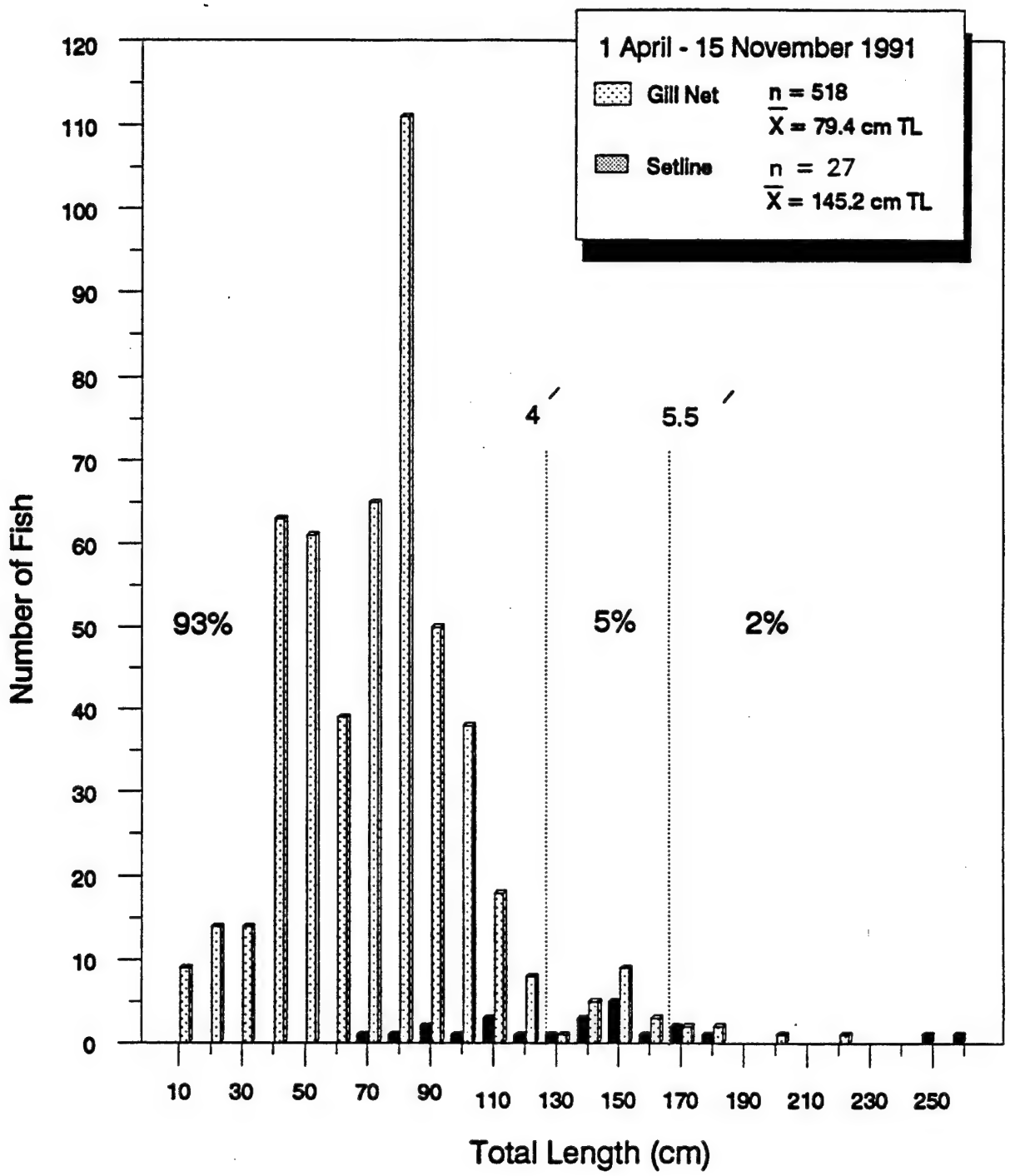


Figure 78. Size distributions of white sturgeon collected in Lower Granite Reservoir, Idaho-Washington during 1 April-7 July and 2 August-15 November 1991.

Table 6. Location and net movement of white sturgeon recaptured during spring-summer (April-July) sampling in Lower Granite Reservoir, Idaho-Washington during 1991.

P.I.T. Tag	Metal Tag	Initial Capture		Recapture		Recapture		Recapture		Net Movement (RM)
		Date	RM	Date	RM	Date	RM	Date	RM	
.....	22	5/27/90	114.6	10/23/90	133.7	11/29/90	116.5	6/29/91	129.2	40.8
7F7F7F1D0A	09	5/27/90	114.6	8/16/90	133.7	4/26/91	129.2	---		23.6
.....	23	5/27/90	114.6	6/30/91	127.0	---		---		12.4
.....	05	5/27/90	114.6	4/01/91	134.5	---		---		19.9
.....	28	5/28/90	115.8	7/06/91	119.9	---		---		4.1
.....	29	5/28/90	115.8	4/01/91	134.5	---		---		18.7
.....	35	5/29/90	116.5	6/22/91	133.7	---		---		17.2
.....	48	5/29/90	116.5	6/22/91	133.7	---		---		17.2
.....	66	6/11/90	137.1	6/14/90	137.1	---		---		0
7F7D016373	83	6/23/90	137.1	8/16/90	133.7	6/28/91	133.7	---		3.4
.....	300	6/28/90	113.7	4/23/91	126.1	---		---		12.4
7F7F7E3009	122	N/A		7/10/90	137.1	6/22/91	133.7	---		3.4
.....	482	7/10/90	137.1	5/15/91	116.5	---		---		20.6
7F7D015D48	159	7/13/90	119.9	4/23/91	126.1	---		---		6.2
.....	141	7/18/90	127.0	6/22/91	133.7	---		---		6.7
7F7D017106	149	7/18/90	127.0	11/17/90	133.7	5/31/91	133.7	---		6.7
7F7F7F0805	140	7/26/90	127.0	6/21/91	116.5	6/29/91	129.2	---		23.2
7F7FD025505	148	7/27/90	133.7	4/20/91	120.7	5/21/91	117.7	---		16
7F7FD015056	233	7/03/90	119.9	6/14/91	133.7	6/18/91	133.7	---		13.8
.....	200	7/03/90	119.9	4/01/91	134.5	---		---		14.6
7F7D016A75	198	7/03/90	119.9	6/07/91	116.5	---		---		3.4
7F7D01587C	231	8/12/90	117.7	4/23/91	126.1	---		---		8.4
7F7D015872	251	8/13/90	117.7	6/07/91	116.5	---		---		1.2

Table 6. (continued)

P.I.T. Tag	Metal Tag	Initial Capture Date	Initial Capture RM	Recapture Date	Recapture RM	Recapture Date	Recapture RM	Net Movement (RM)
.....	221	8/16/90	133.7	7/02/91	116.5	—		17.2
7F7D015F45	245	8/16/90	133.7	5/31/91	133.7	—		0
.....	217	8/16/90	133.7	7/01/91	137.1	—		3.4
.....	273	8/18/90	127.0	4/01/91	134.5	—		7.5
.....	N/T	8/23/90	137.1	4/26/91	129.2	—		7.9
7F7D015557	379	10/23/90	133.7	4/30/91	131.6	—		2.1
.....	296	10/23/90	133.7	4/01/91	134.5	—		0.8
.....	533	11/01/90	110.5	7/07/91	131.6	—		21.1
7F7D016650	334	4/01/91	134.5	4/23/91	126.1	—		8.4
7F7D01686F	330	4/01/91	134.5	6/18/91	129.2	—		5.3
7F7D015708	574	4/21/91	122.6	5/29/91	116.5	—		6.1
7F7D01540D	45	4/30/91	131.6	5/29/91	116.5	—		15.1
7F7D016E22	566	5/29/91	116.5	6/02/91	110.5	—		6.0
7F7D016B76	451	5/09/91	129.2	6/22/91	133.7	—		4.5

Table 7. Location and net movement of white sturgeon recaptured during fall-winter (August-November) sampling in Lower Granite Reservoir, Idaho-Washington during 1991.

P.I.T. Tag	Metal Tag	Initial Capture		Recapture		Recapture		Recapture		Net Movement (RM)
		Date	RM	Date	RM	Date	RM	Date	RM	
—	62	6/6/90	133.7	8/29/91	127.0	—		—		6.7
7F7F770178	13	7/26/90	127.0	10/02/91	129.2	—		—		2.2
7F7F763213	80	6/18/90	127.0	10/10/91	131.6	—		—		4.6
7F7F766E70	86	6/23/90	137.1	10/06/91	116.5	—		—		20.6
7F7F76735D	96	6/18/90	127.0	9/11/91	133.7	—		—		6.7
7F7F775423	142	7/13/90	119.9	9/07/91	133.7	—		—		13.8
7F7F767244	168	7/14/90	117.7	10/06/91	116.5	—		—		1.2
7F7E775E58	184	6/28/90	113.6	8/11/91	117.7	—		—		4.1
—	189	7/03/90	119.9	10/20/91	127.0	—		—		7.1
7F7D017C06	243	6/14/91	133.7	7/08/91	133.7	8/15/91	137.1	—		3.4
7F7F775D11	259	11/03/90	137.1	9/06/91	127.0	—		—		10.1
—	313	11/21/90	110.5	6/28/91	137.1	11/21/91	133.7	—		3.4
7F7F77683F	320	8/04/91	127.0	10/07/91	117.7	—		—		9.3
—	349	6/28/91	133.7	10/07/91	133.7	—		—		0
7F7F776920	352	5/29/90	116.5	8/11/91	117.7	—		—		1.2
7F7F7F0967	356	4/11/91	114.2	6/11/91	117.7	6/29/91	129.2	9/13/91	129.2	15
7F7D017446	388	4/30/91	131.6	10/07/91	133.7	—		—		2.1
7F7D015E2C	398	10/23/90	133.7	4/30/91	131.6	9/12/91	131.6	—		2.1
7F7D02063A	422	5/22/91	127.0	8/01/91	127.0	—		—		0
—	440	4/01/91	134.5	10/17/91	137.1	—		—		2.6
7F7F7F255F	447	4/20/91	134.5	9/01/91	129.2	—		—		5.3
7F7F775F6E	486	4/16/91	117.7	10/22/91	129.2	—		—		11.5
—	488	4/23/91	126.1	10/07/91	133.7	—		—		7.6
—	497	4/14/91	117.7	10/10/91	131.6	—		—		13.9

Table 7. (continued)

P.I.T. Tag	Metal Tag	Initial Capture		Recapture		Recapture		Recapture		Net Movement (RM)
		Date	RM	Date	RM	Date	RM	Date	RM	
—	508	7/02/91	116.5	8/04/91	127.0	10/10/91	131.6	—		15.1
7F7D01797B	518	6/21/91	116.5	8/10/91	116.5	—		—		0
7F7F72530	530	6/21/91	116.5	9/09/91	137.1	—		—		20.6
7F7D077628	538	6/21/91	116.5	10/07/91	133.7	—		—		17.2
7F7F7F1C15	553	6/21/91	116.5	10/07/91	133.7	—		—		17.2
7F7D01700B	555	6/22/91	133.7	8/12/91	133.7	—		—		0
7F7D017827	559	6/26/91	131.6	10/07/91	133.7	—		—		2.1
7F7F77670F	609	7/03/90	119.9	9/06/91	127.0	—		—		7.1
7F7F763A01	610	8/15/91	137.1	9/09/91	137.1	—		—		0
—	623	6/27/90	137.1	7/27/90	133.7	9/09/91	137.1	—		6.8
7F7F775F57	635	7/26/90	133.7	8/11/91	133.7	—		—		0
7F7F763141	637	8/23/91	117.7	9/22/91	110.5	—		—		2.2
7F7F76763D	640	8/15/91	137.1	10/07/91	133.7	—		—		3.4
7F7F766E24	655	8/01/91	129.2	10/07/91	133.7	—		—		4.5
7F7F774C3B	674	7/10/90	137.1	10/25/91	133.7	—		—		3.4
7F7D01630E	678	6/07/91	116.5	7/06/91	133.7	—		—		17.2
—	687	11/10/90	110.5	7/07/91	131.6	10/22/91	129.2	—		23.5
7F7F776454	764	7/10/90	137.1	10/17/91	137.1	—		—		0
7F7F762A2B	—	10/30/91	137.1	11/11/91	137.1	—		—		0
7F7F766F69	—	N/A		10/25/91	133.7	—		—		—
7F7F775D00	216	8/16/90	133.7	10/25/91	133.7	—		—		0
7F7F774B7B	101	6/11/91	137.1	10/17/91	137.1	—		—		0
7F7F76706F	91	6/27/90	137.1	10/17/91	137.1	—		—		0
—	396	N/A		10/07/91	133.7	—		—		—

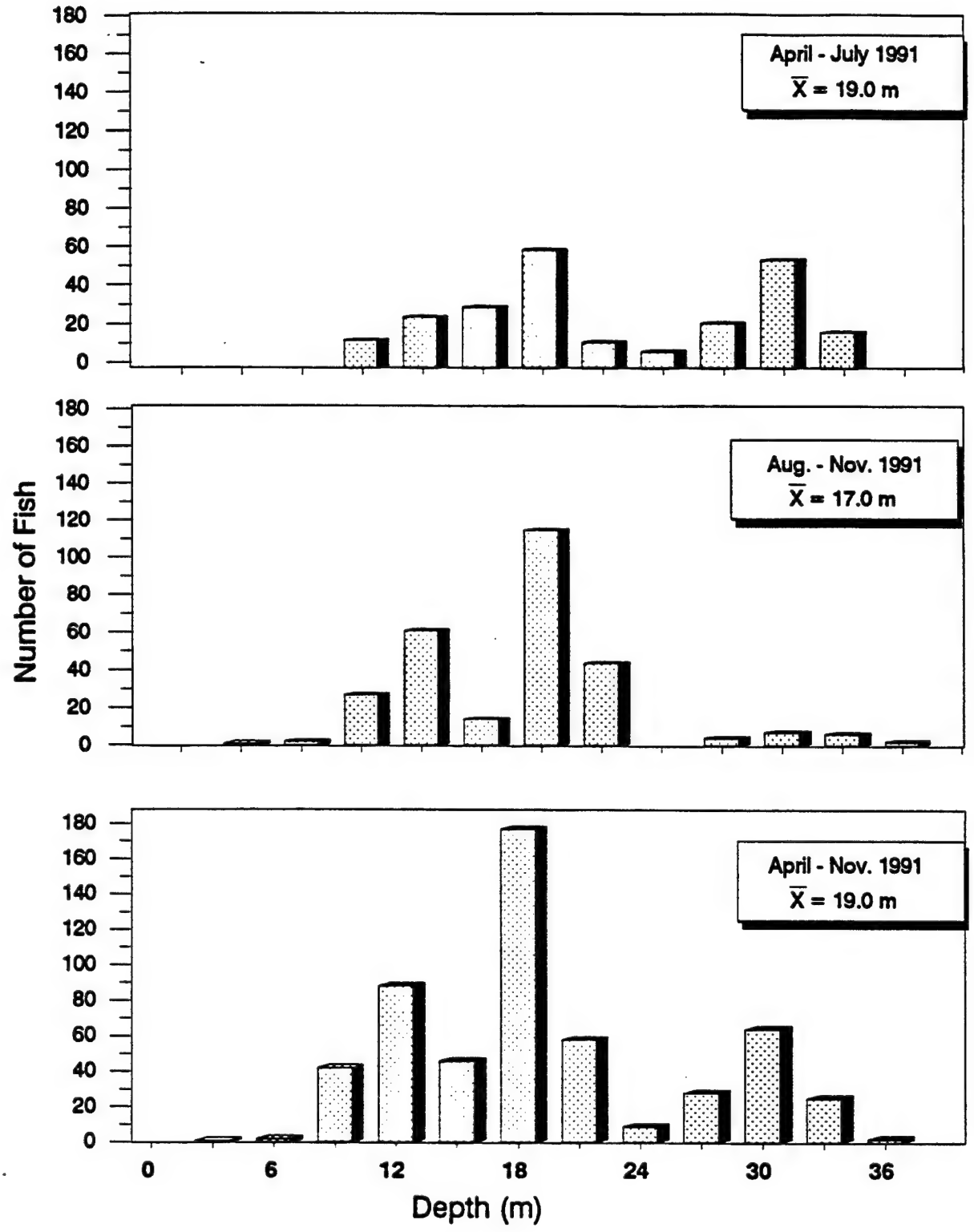
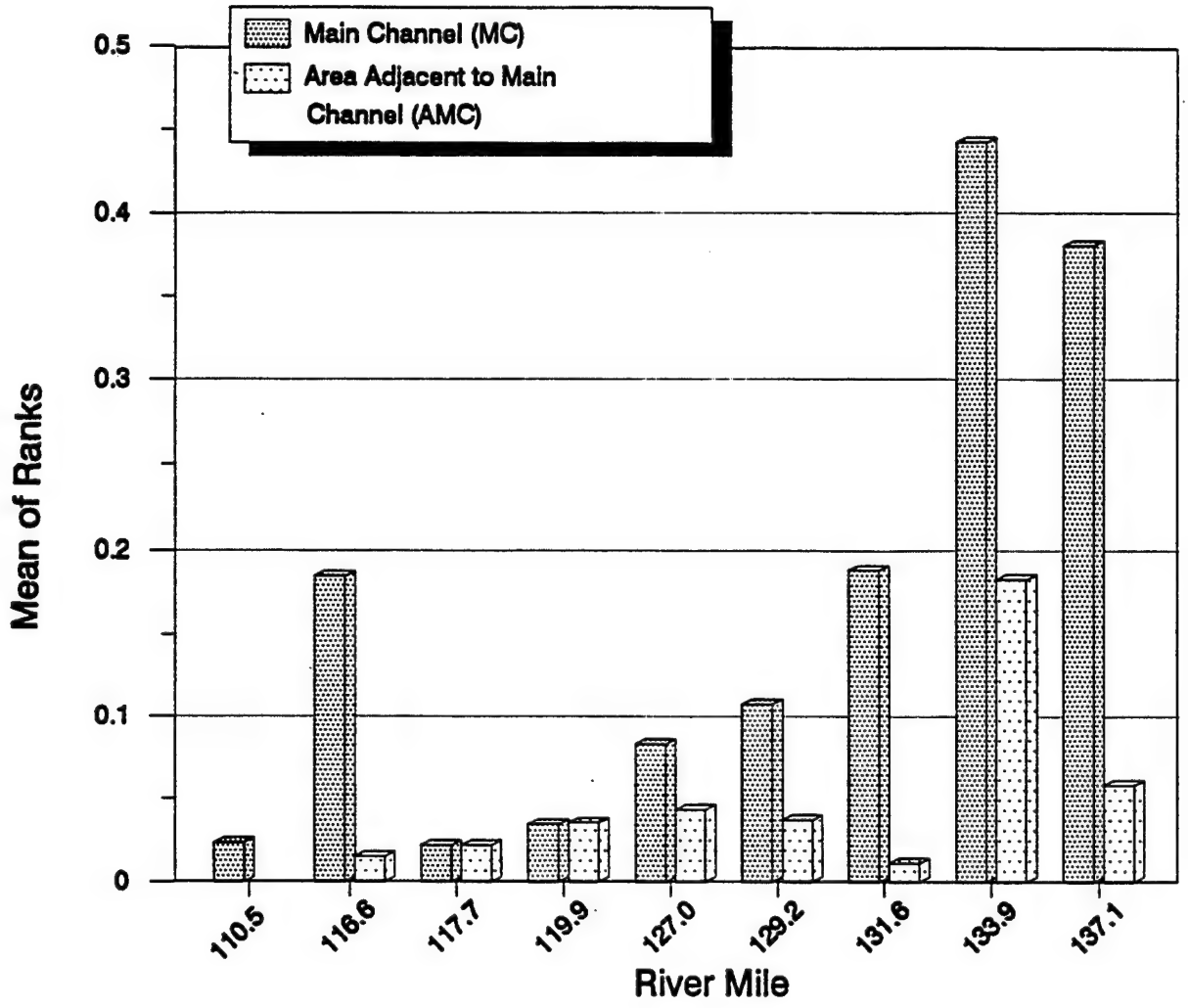


Figure 79. Relationships between depth and number of white sturgeon captured in Lower Granite Reservoir, Idaho-Washington during 1991.



Channel Comparisons within Stations

	110.5	116.6	117.7	119.9	127.0	129.2	131.6	133.9	137.1
MC									
AMC									

Figure 80. Comparison of white sturgeon catches between the main channel (MC) and areas adjacent to the main channel (AMC) within sample locations in Lower Granite Reservoir, Idaho-Washington during 1991. Channels joined by a vertical line indicate statistical nonsignificance ($P > 0.05$).

Surface and bottom current velocities periodically recorded throughout the sample reach ranged from 0.0-2.27 ft/s (0.0-0.81 m/s) with highest velocities recorded in May near Port of Wilma (RM 133.7) and Red Wolf Crossing Bridge (RM 137.1). Higher velocities were maintained at upper reservoir locations during the sampling period, and main channel velocities generally were higher than adjacent bench velocities (Figure 81). Bottom current velocities in areas utilized by sturgeon ranged from 0.0-1.7 ft/s (0.0-0.51 m/s) with a mean of 0.32 ft/s (0.096 m/s).

Water temperatures recorded from main channel and bench areas ranged from 8.6-27°C during 1991 (Figure 82). A difference of 5.5°C was the largest recorded change in temperature from surface to bottom depths in the main channel in the summer. The reservoir was homothermous at 9.0°C by 17 November, 1991. Temperatures in the main channel and adjacent bench areas differed by a few degrees throughout sampling.

Dissolved oxygen remained slightly higher at upriver sample stations, however, readings > 5.6 mg/l were maintained throughout the reservoir during 1991 (Figure 83). No significant difference ($P > 0.05$) in dissolved oxygen was apparent between main channel and adjacent bench areas.

Number of crayfish trapped at sampling transects ranged from 0.0-69 during 1991 (Figure 84). Crayfish numbers collected from 1990 were included to increase the data set for analysis. Abundance of crayfish

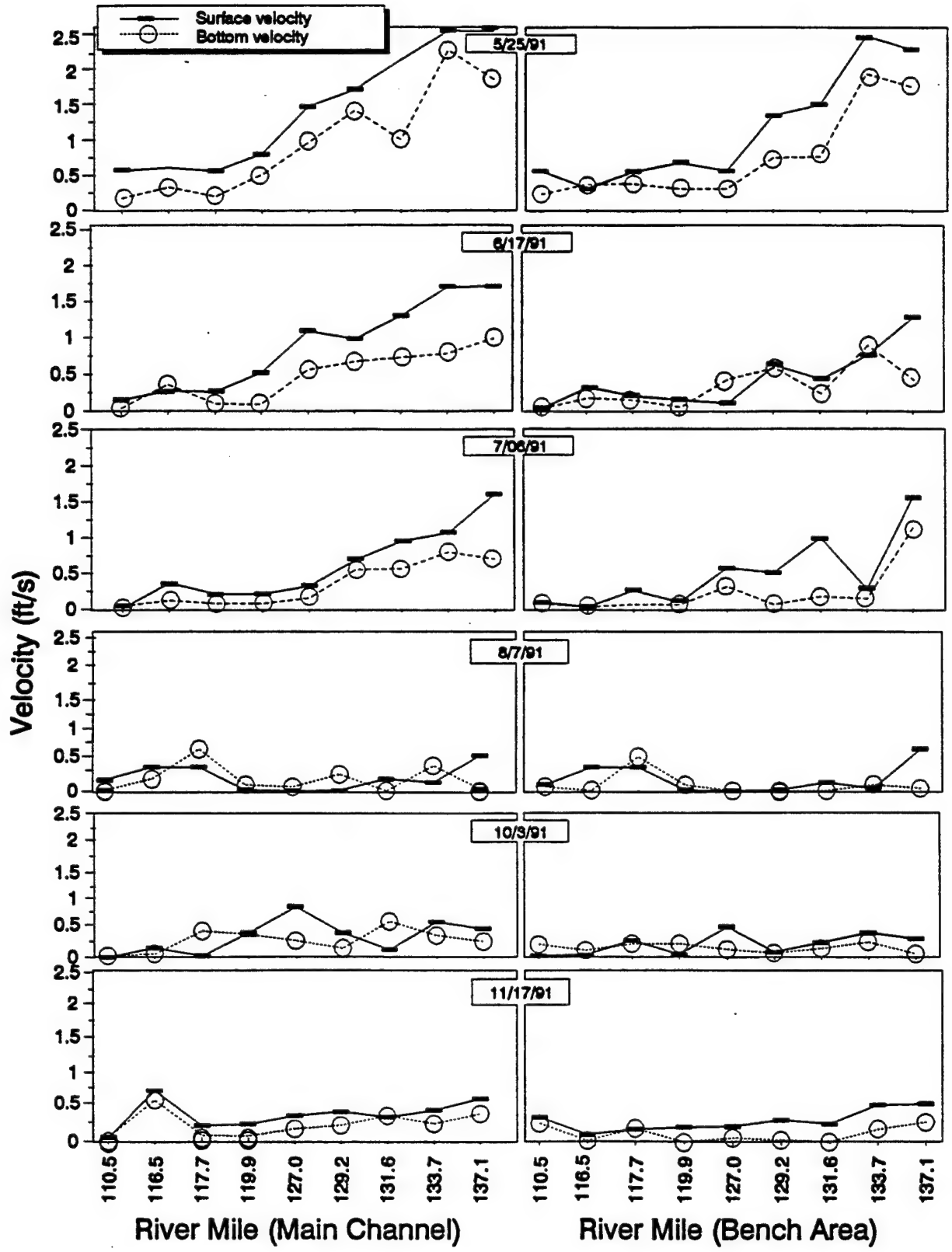


Figure 81. Comparison of water velocities at locations sampled for white sturgeon in Lower Granite Reservoir, Idaho-Washington during 1991.

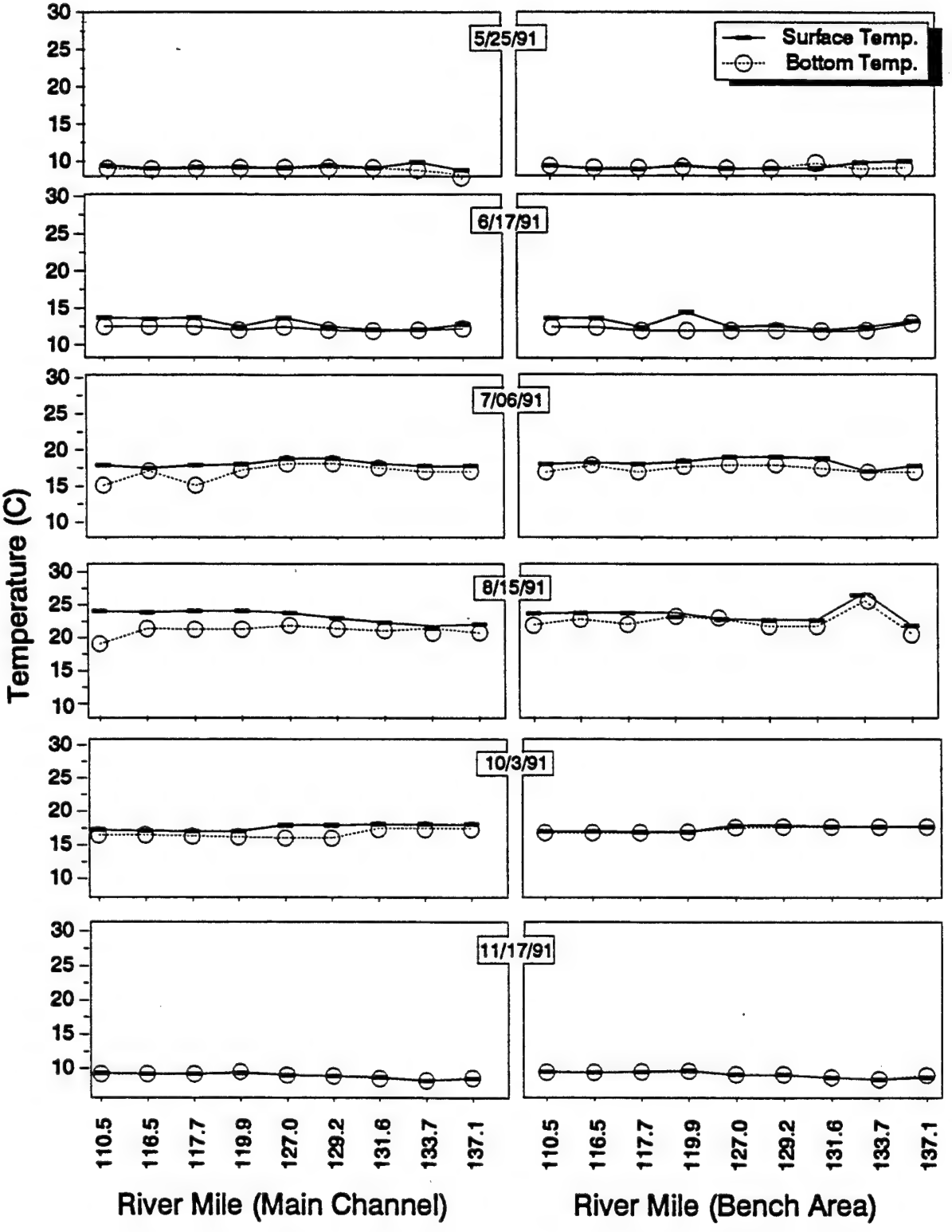


Figure 82. Comparison of temperature at locations sampled for white sturgeon in Lower Granite Reservoir, Idaho-Washington during 1991.

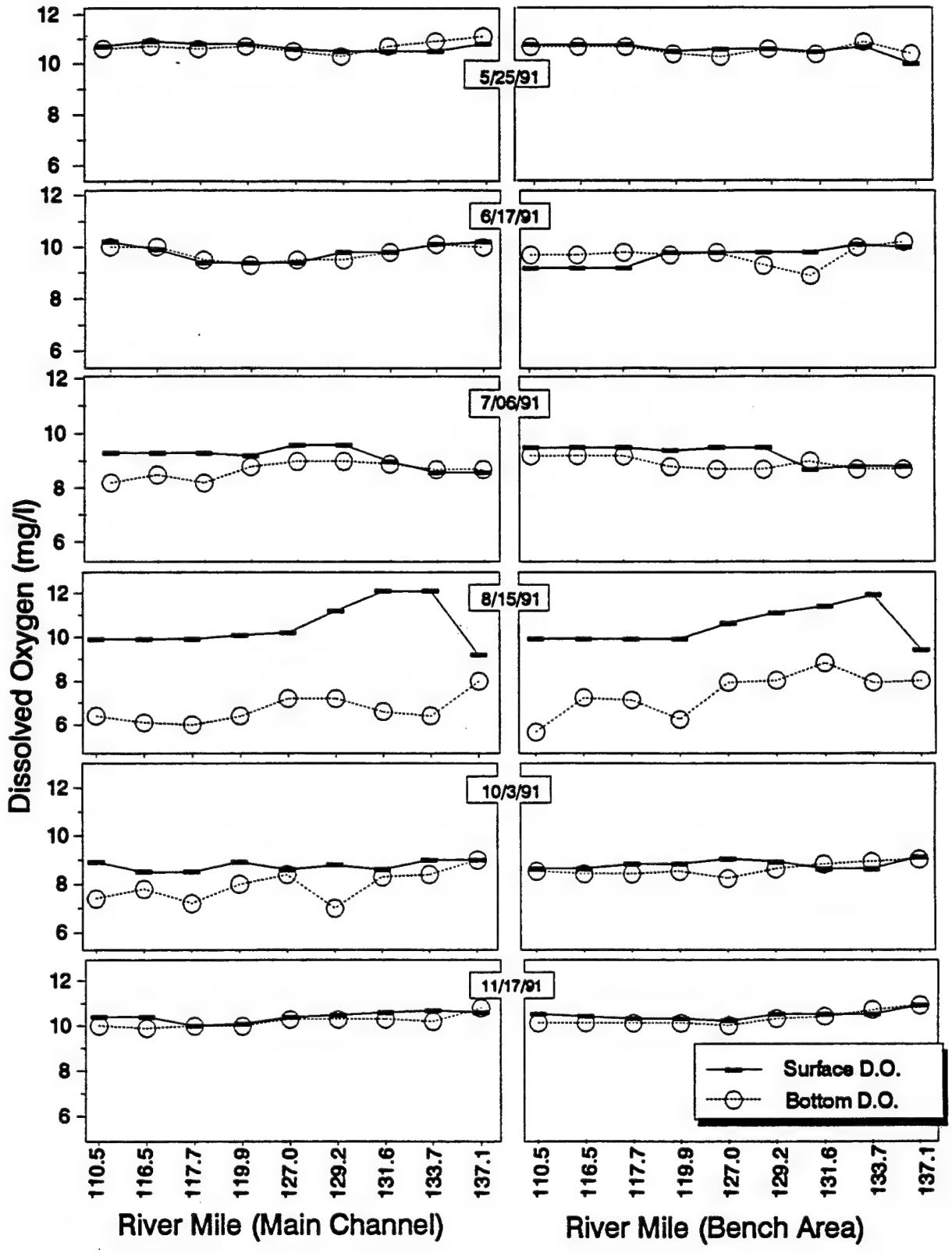


Figure 83. Comparison of dissolved oxygen at locations sampled for white sturgeon in Lower Granite Reservoir, Idaho-Washington during 1991.

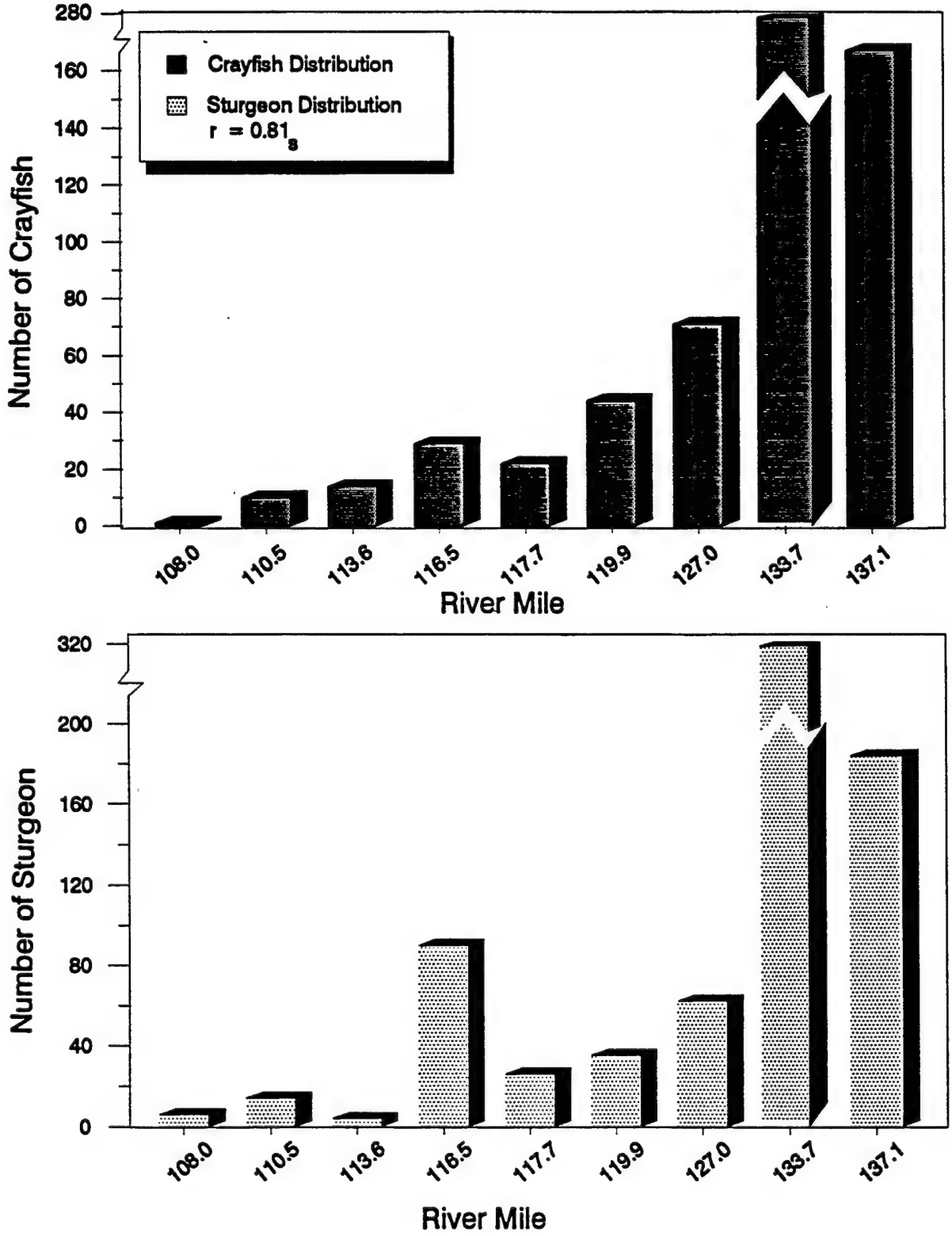


Figure 84. Spearman's rank order correlation analysis between crayfish and white sturgeon at sample stations in Lower Granite Reservoir, Idaho-Washington during 1990-1991.

and white sturgeon yielded a correlation coefficient of 0.81 using Spearman's rank order correlation analysis.

DISCUSSION

Sampling during 1990 and 1991 revealed a much higher population of white sturgeon in Lower Granite Reservoir than earlier sampling suggested (Bennett and Shrier 1986; Bennett et al. 1988, 1989). Over 540 sturgeon were captured in 1991 yielding an overall population estimate of approximately 1,300 sturgeon > 40 cm TL for 1990-1991.

Length frequency data of sturgeon collected during 1991 were similar to 1990 with each year exhibiting a high percent (> 90%) of sturgeon < 125 cm TL. Cochanuer (1983) determined sturgeon < 125 cm were juvenile fish. Approximately 93% of the sturgeon sampled during 1991 were < 125 cm suggesting a predominantly juvenile population was inhabiting Lower Granite Reservoir. Lukens (1985) suggested the upper end of the Lower Granite pool may serve as rearing for juvenile sturgeon which corroborates our findings.

Capture of 14 sturgeon measuring < 20 cm TL during 1990 and 1991 suggesting recent reproduction occurred in this segment of the Snake River. We believe these small sturgeon were age-0 fish. Access to free flowing, riverine habitat upstream from the Lower Granite pool provides a combination of spawning and rearing habitat in the river and reservoir. Spawning sites have rocky substrate with swift water velocities (Scott and Crossman 1973). Spawning areas usually have larger substrate, but whether sturgeon select for substrate or the

substrate type used is an artifact of water velocity is unclear (Hanson et al. 1992).

Low gill net and setline captures of larger adult sturgeon suggested these fish were not using the Lower Granite pool in the same abundance as smaller sturgeon. Eleven sturgeon > 170 cm TL were sampled during 1991 with gill nets and setlines. Setline rigging in Lower Granite Reservoir was adopted from methods described in the Kootenai River sturgeon investigations (Apperson and Anders 1990). Evaluation of setline gear by Oregon Department of Fish and Wildlife determined sturgeon > 90 cm fork length (FL) fully recruited to the gear (Nigro 1989). However, setline catches in Lower Granite Reservoir remained low for size classes > 90 cm FL .

Habitat conditions in the upper reservoir appear more suitable for white sturgeon than in the lower reservoir. Apperson and Anders (1990, 1991) reported sturgeon in the Kootenai River utilizing velocities ranging from 0.031-0.61 m/s. Velocities of this range in Lower Granite Reservoir were generally maintained in upper reservoir areas. Dissolved oxygen remained at sufficient levels throughout the reservoir during 1991. Temperatures were not significant between sample locations, although threshold and temperature changes may initiate activity and seasonal migrations (Coon et al. 1977; Haynes et al. 1978).

Common food items of sturgeon in the Snake River are fish, crayfish, aquatic insects, dipteran larvae, snails and clams (Coon et al. 1977; Cochnauer 1983). Young-of-the-year sturgeon (< 20 cm) begin feeding on small crustaceans and seek various aquatic insect larvae as

they become larger (Bajkov 1949; Galbreath 1979; Cochnauer 1983; Conte et al. 1988). McCabe and Hinton (1990) also reported *Corophium salmonis* an important food item for sturgeon < 72 cm FL in the lower Columbia River. Corophium numbers in Lower Granite appear low (Bennett et al. 1991). Crayfish are more abundant and highest numbers of crayfish collected in Lower Granite Reservoir were at upper reservoir locations. High crayfish abundance may account for the high abundance of sturgeon occurring in these areas. High larval fish abundance reported by Bennett et al. (1991) above RM 127.0 may also contribute to food resources of smaller sturgeon.

White sturgeon were not evenly distributed in Lower Granite Reservoir with over half of the sampled fish utilizing the upper third of the reservoir. High catch rates were consistent at RM 133.7 and 137.1. Deep water (> 20 m; > 65.6 ft) areas of the lower and mid-reservoir sections were not considered significant habitat areas since captures were markedly lower than at upstream locations. Mean catch rates from sample locations above RM 129.2 were significantly higher than downstream, suggesting upstream areas provide more suitable habitat for sturgeon.

Objective 3.. To estimate juvenile salmonid fish consumption by northern squawfish in Lower Granite Reservoir;

METHODS

Stomachs of northern squawfish > 250 mm collected from 1 April through 30 July, 1991 by all gear types between RM 112.5 and RM 132.0 were examined for food items. Captured squawfish were measured to total length (mm), anesthetized and the entire digestive tract was removed and frozen for later analysis.

Daily consumption rates of juvenile salmonids were determined by procedures developed by Vigg et al. (1988). Stomach contents were sorted, enumerated and identified to the lowest possible taxon. Unidentified materials, parasites and nonfood items were recorded and excluded from dietary calculations. Prey items were blotted dry and weighed (mg). Crustaceans were identified to genus or family, while insects were identified to order. Undigested fish were identified to species, when possible, and measured fork length mm.

Bone morphology identification techniques (Hansel et al. 1988) were used to identify partially digested fish. For advanced digested fishes, fork lengths were estimated from standard or nape to tail lengths or bone lengths using regression equations developed from known specimens.

Partially digested fish remains from more than one prey fish were weighed together and apportioned to the weight of an individual prey fish based on the relative weight and degree of digestion. When only digested fish parts remained and the relative size of each prey fish

could not be determined, the total weight of the parts were divided equally among fish in the stomach (Vigg et al. 1988).

When diagnostic bones for unknown salmonids (ie. juvenile chinook salmon or juvenile steelhead) were encountered, the species identification was determined by comparing the range of lengths of salmonids captured by our sampling (Objective 1) within 7 days of the capture. When prey lengths overlapped those from captured fish, identification beyond salmonids were not possible.

RESULTS

A total of 218 northern squawfish were captured in Lower Granite Reservoir in 1991. The majority (59%) were captured at upriver sampling stations (RM 127-137.5) followed by mid-reservoir (RM 126-112; 17%) and lower reservoir locations near reference station 6 (14%; Figure 85). The lowest number collected (10%) occurred near the forebay (RM 111-107.5). The majority of squawfish (75%) sampled ranged in length between 300-450 mm with a mean length of 388 mm (Figure 86).

Daily Ration

Seasonal total daily ration for northern squawfish during spring (all dates combined) was 6.098 mg/g/d of all prey fishes (Figure 87). Total daily ration was lowest for non-salmonids (castostomids and unidentified non-salmonids) and intermediate for juvenile steelhead. Ration estimates for juvenile chinook were intermediate between non-salmonids and steelhead.

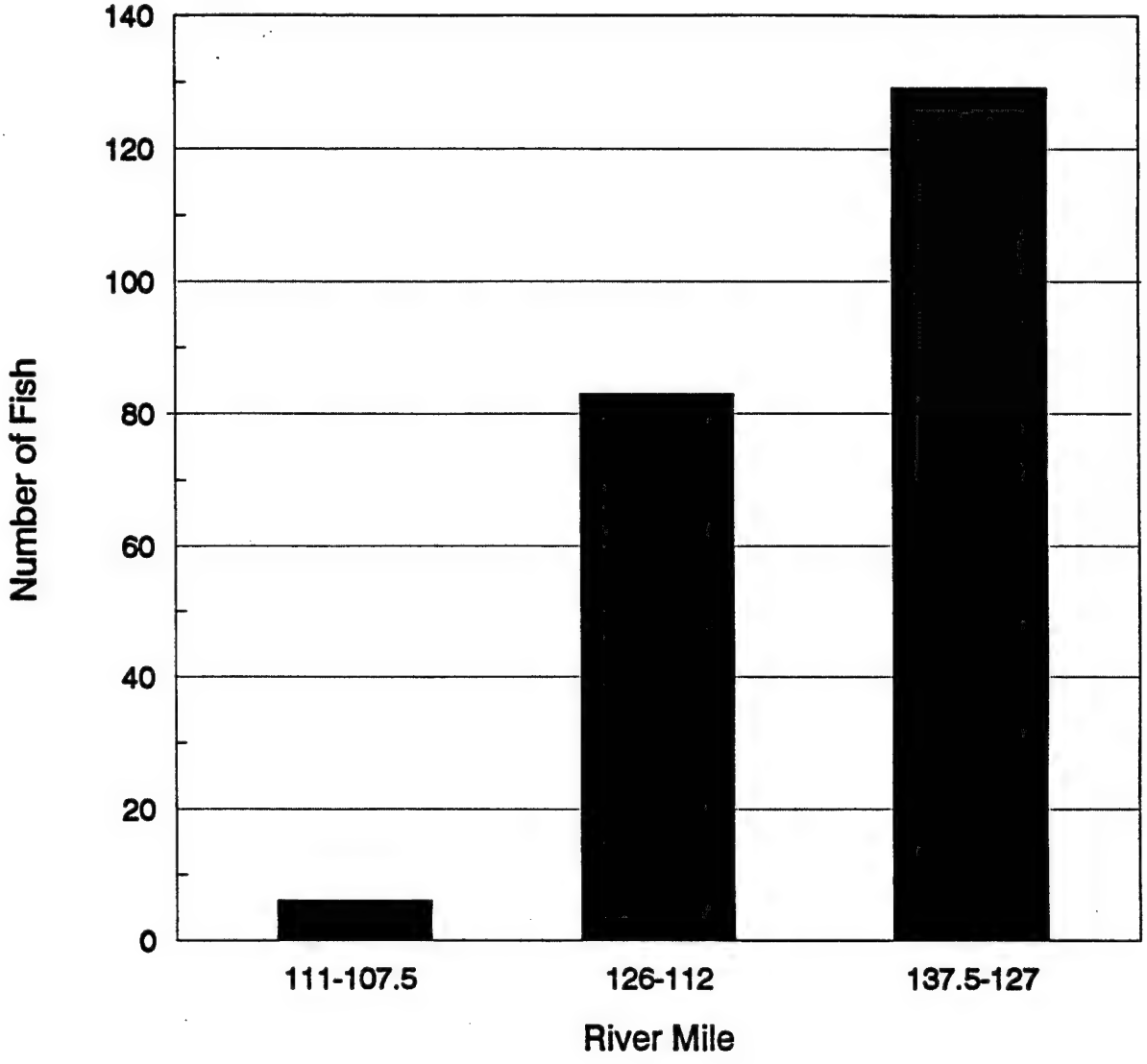


Figure 85. Number of northern squawfish captured in Lower Granite Reservoir, Idaho-Washington during 1991.

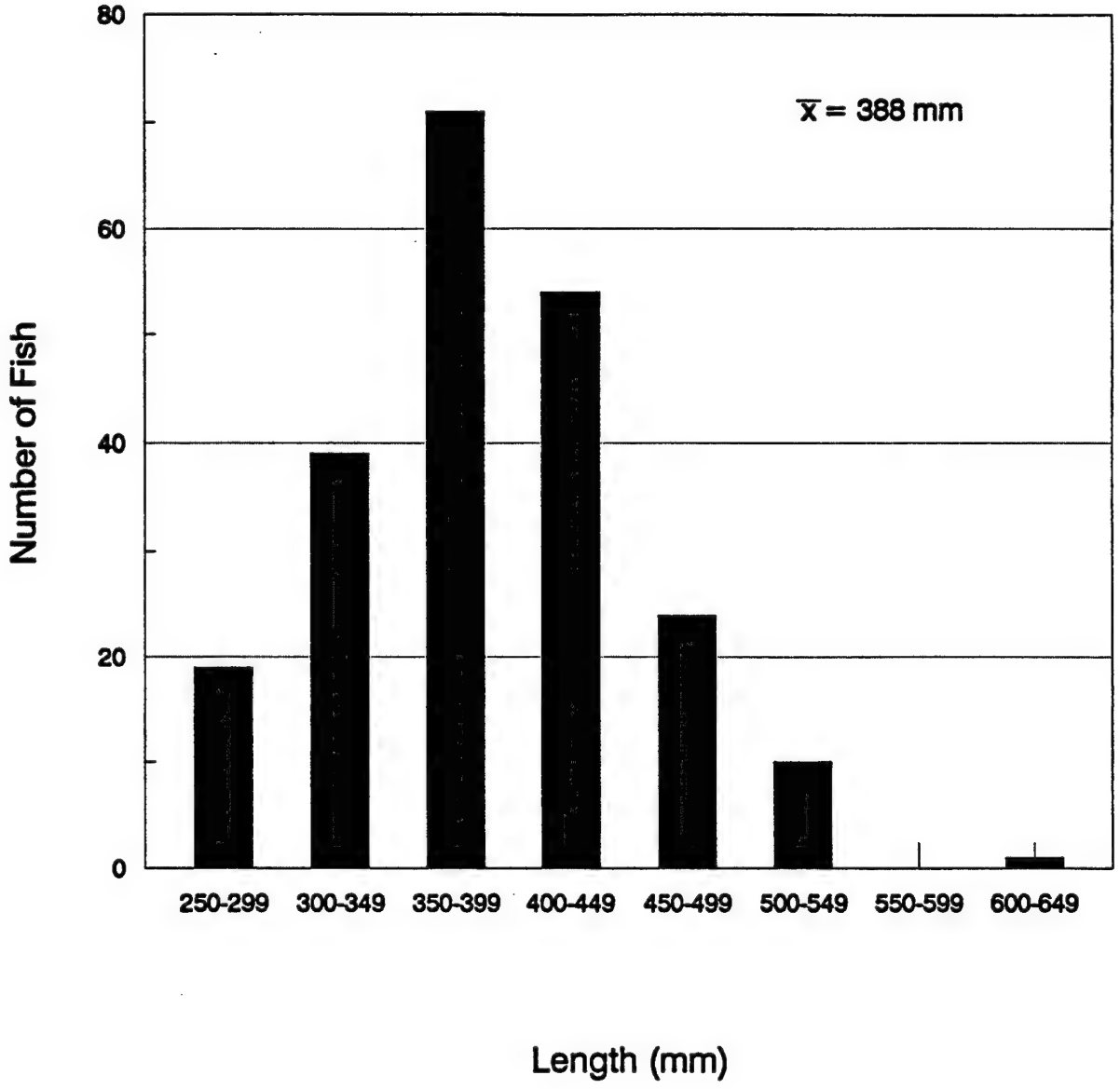


Figure 86. Length frequency of northern squawfish captured in Lower Granite Reservoir, Idaho-Washington during spring 1991.

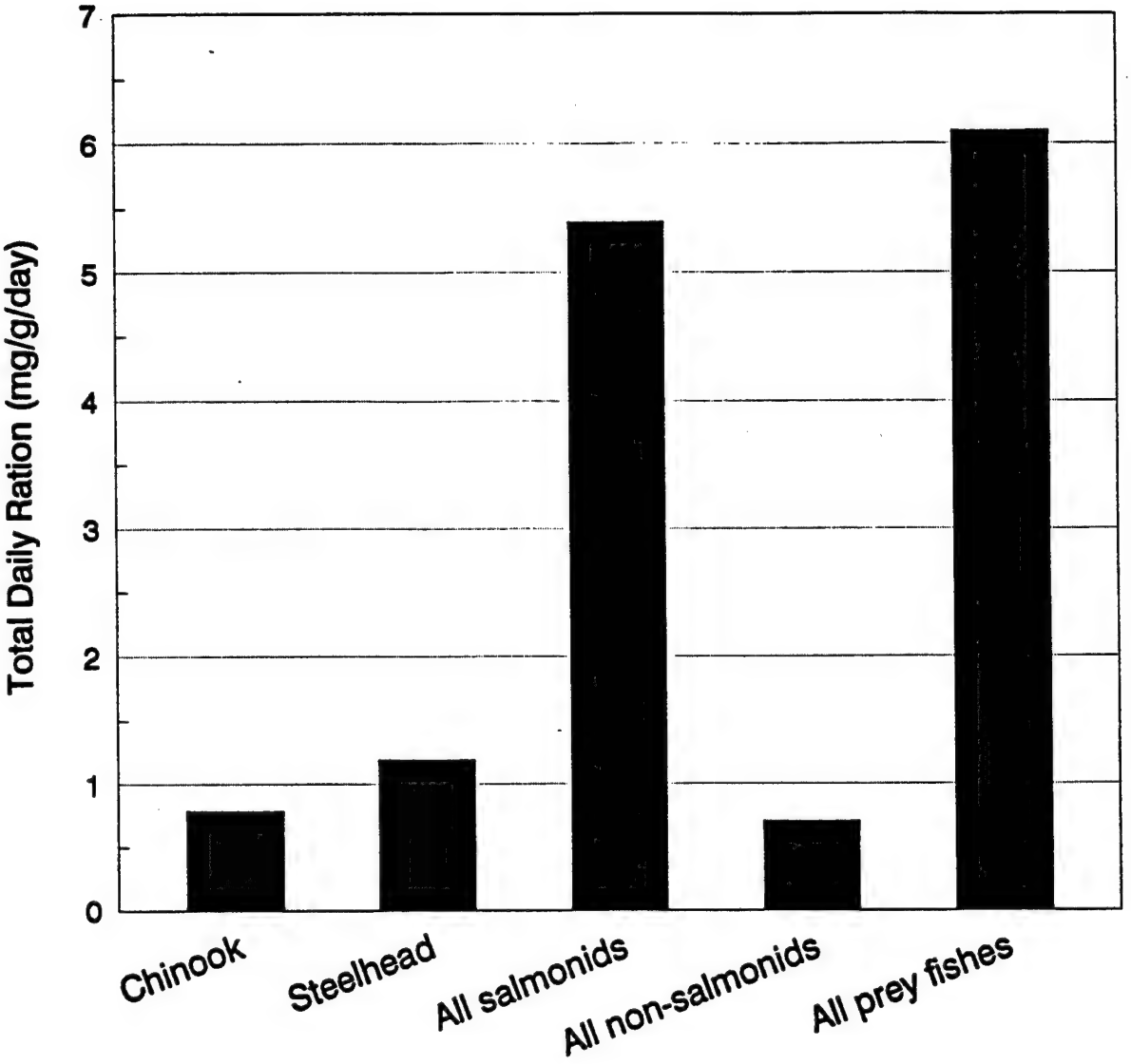


Figure 87. Total daily ration of fishes consumed by northern squawfish in Lower Granite Reservoir, Idaho-Washington during 1991.

Monthly ration estimates of northern squawfish increased from April to May and decreased in June (Figures 88-89). Mean monthly total daily ration estimate of all prey fishes consumed by northern squawfish during April was 6.147 mg/g/d, while those of juvenile chinook salmon and non-salmonids were about 0.893 mg/g/d (Figure 88). Northern squawfish containing salmonids had a total daily ration of 5.394 mg/g/d. Steelhead did not contribute substantially to squawfish diets during April which indicates the majority of salmonids in the diet were probably chinook.

The mean monthly total daily ration estimate of northern squawfish for May was 7.206 mg/g/d for all prey fishes (Figure 89). Squawfish total daily ration of juvenile chinook salmon was lower (0.687 mg/g/d) than that for juvenile steelhead (3.332 mg/g/g) and total daily ration of all salmonids was 7.141 mg/g/d. Non-salmonids were rarely observed in squawfish stomachs during May.

Mean monthly total daily ration estimate for northern squawfish in June was 4.629 mg/g/d of all prey fishes (Figure 90). Juvenile chinook salmon were not observed in squawfish stomachs during June. Consumption of juvenile steelhead was 1.904 mg/g/d and reflected lower salmonid consumption than in April and May. Squawfish had a total daily ration of 1.904 mg/g/d of all salmonids during May, probably a result of decreased smolt availability. Total daily ration for squawfish of all non-salmonids was highest in June 2.725 mg/g/d.

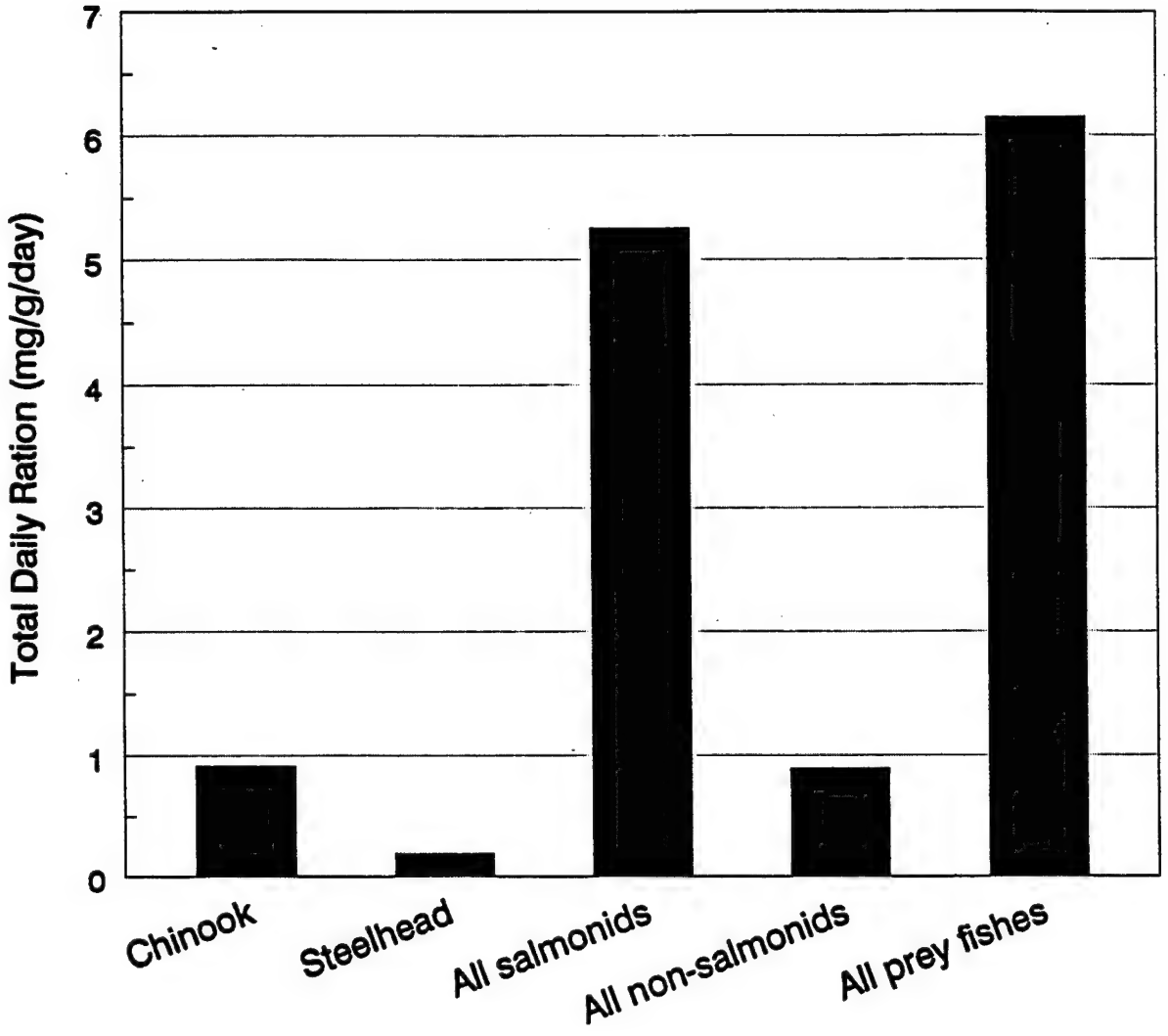


Figure 88. Total daily ration of fishes consumed by northern squawfish in Lower Granite Reservoir, Idaho-Washington during April 1991.

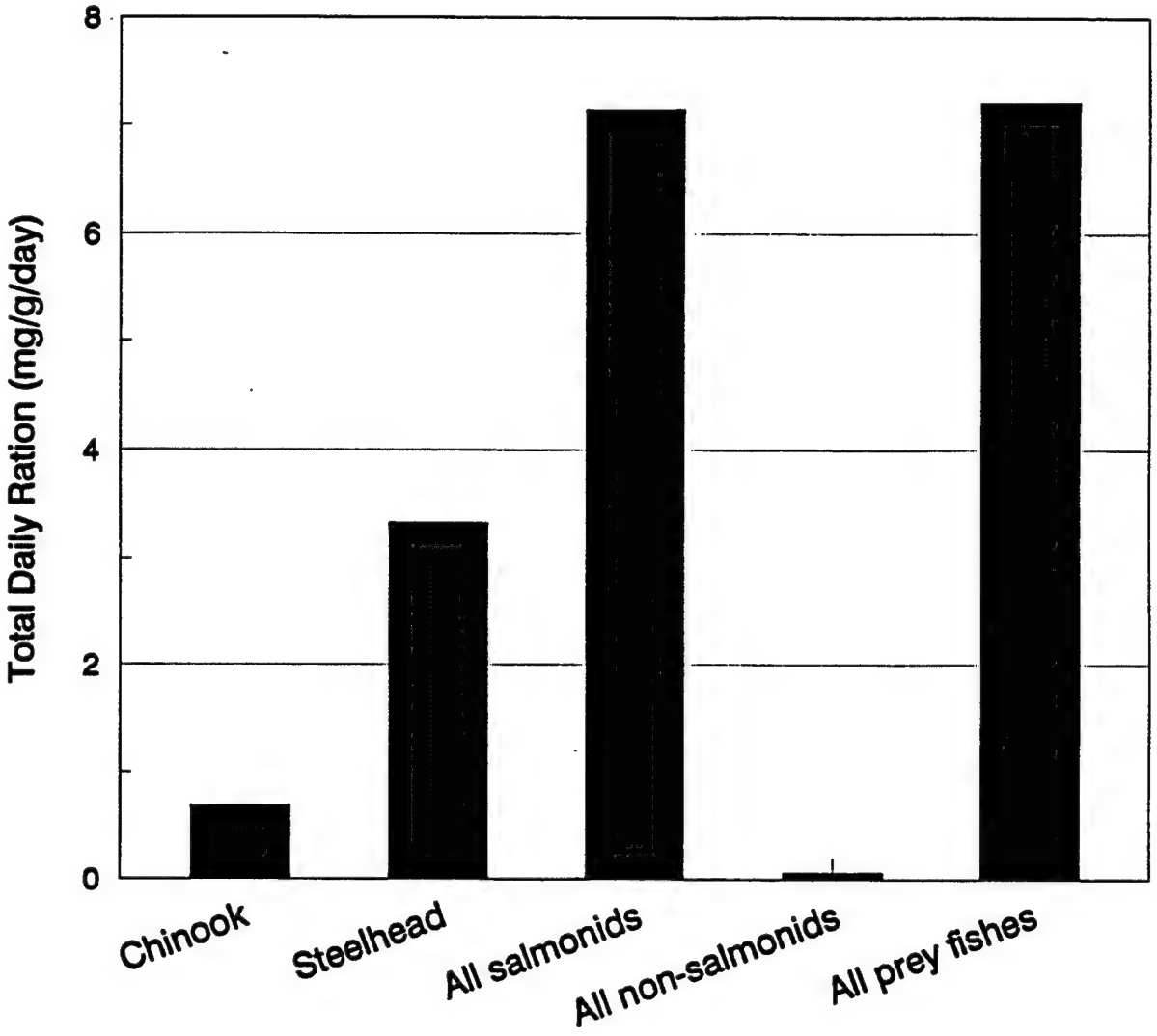


Figure 89. Total daily ration of fishes consumed by northern squawfish in Lower Granite Reservoir, Idaho-Washington during May 1991.

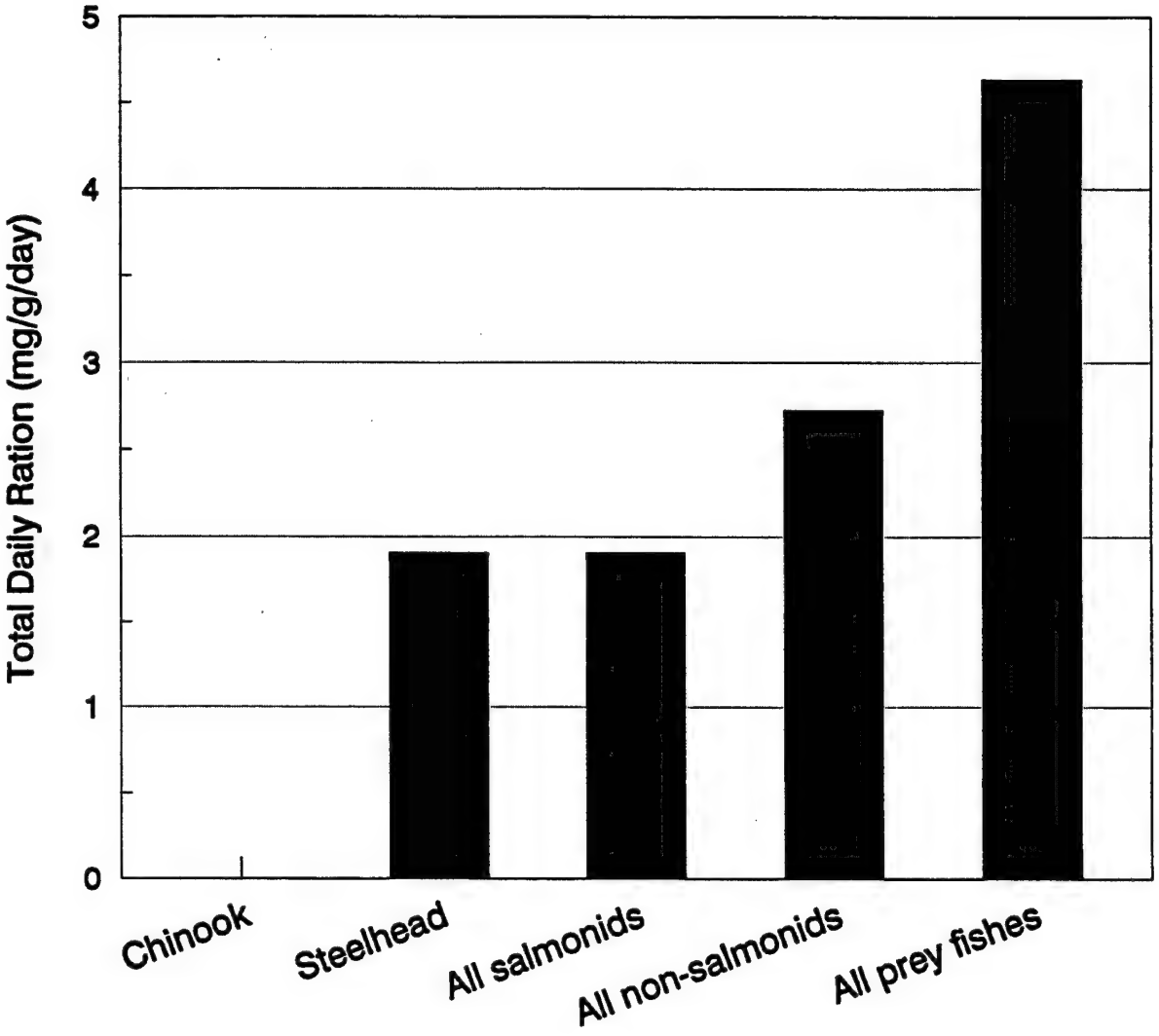


Figure 90. Total daily ration of fishes consumed by northern squawfish in Lower Granite Reservoir, Idaho-Washington during June 1991.

Consumption Estimates

The consumption estimate of all prey fishes by northern squawfish > 250 mm during the spring-summer season was 0.128 prey/predator/d (Figure 91). Mean seasonal consumption rates of squawfish for juvenile chinook salmon and steelhead were 0.0384 prey/predator/d and 0.0129 prey/predator/d, respectively. Mean seasonal consumption rate by squawfish for all juvenile salmonids was 0.131 prey/predator/d, while mean consumption rate of non-salmonids during this period was 0.008 prey/predator/d.

The highest mean monthly consumption rate of juvenile salmonids by squawfish was in April at 0.162 prey/predator/d and coincided with the inception of downstream smolt migration in Lower Granite Reservoir (Figure 92). The mean monthly consumption rate of squawfish for juvenile chinook salmon was also highest in April (0.047 prey/predator/d). Mean monthly consumption rates of juvenile steelhead (0.003 prey/predator/d) and non-salmonids (0.007 prey/predator/d) were lowest in April.

The mean monthly consumption rate of juvenile salmonids by squawfish in May was 0.102 prey/predator/d (Figure 93). Northern squawfish had a mean monthly consumption rate of 0.019 for juvenile chinook salmon prey/predator/d. Mean monthly consumption rate was highest of all months in May for juvenile steelhead at 0.0384 prey/predator/d.

The mean monthly consumption rates of northern squawfish for all prey fishes was lowest in June (0.086 prey/predator/d) and highest for

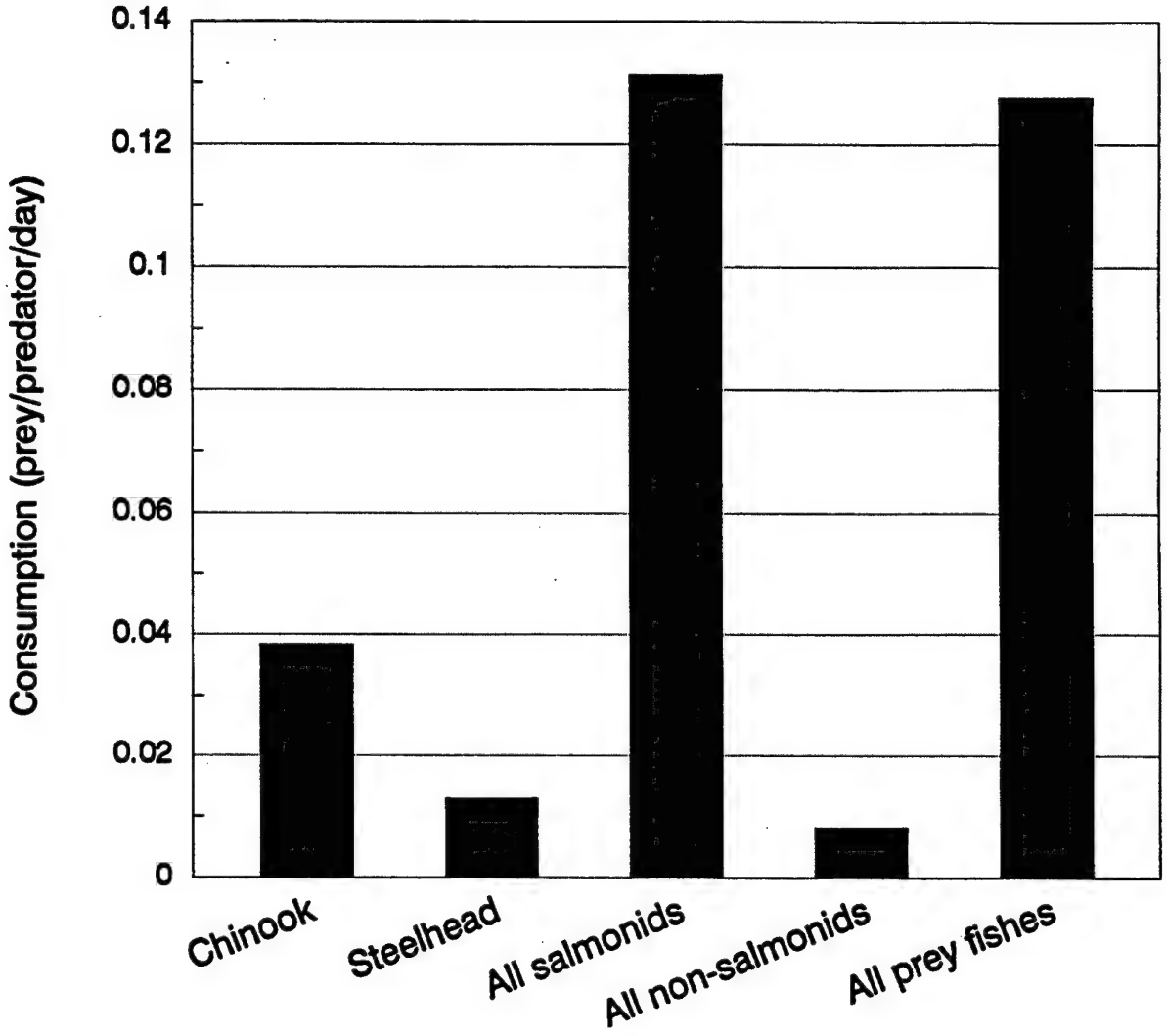


Figure 91. Consumption rates of fishes by northern squawfish in Lower Granite Reservoir, Idaho-Washington during 1991.

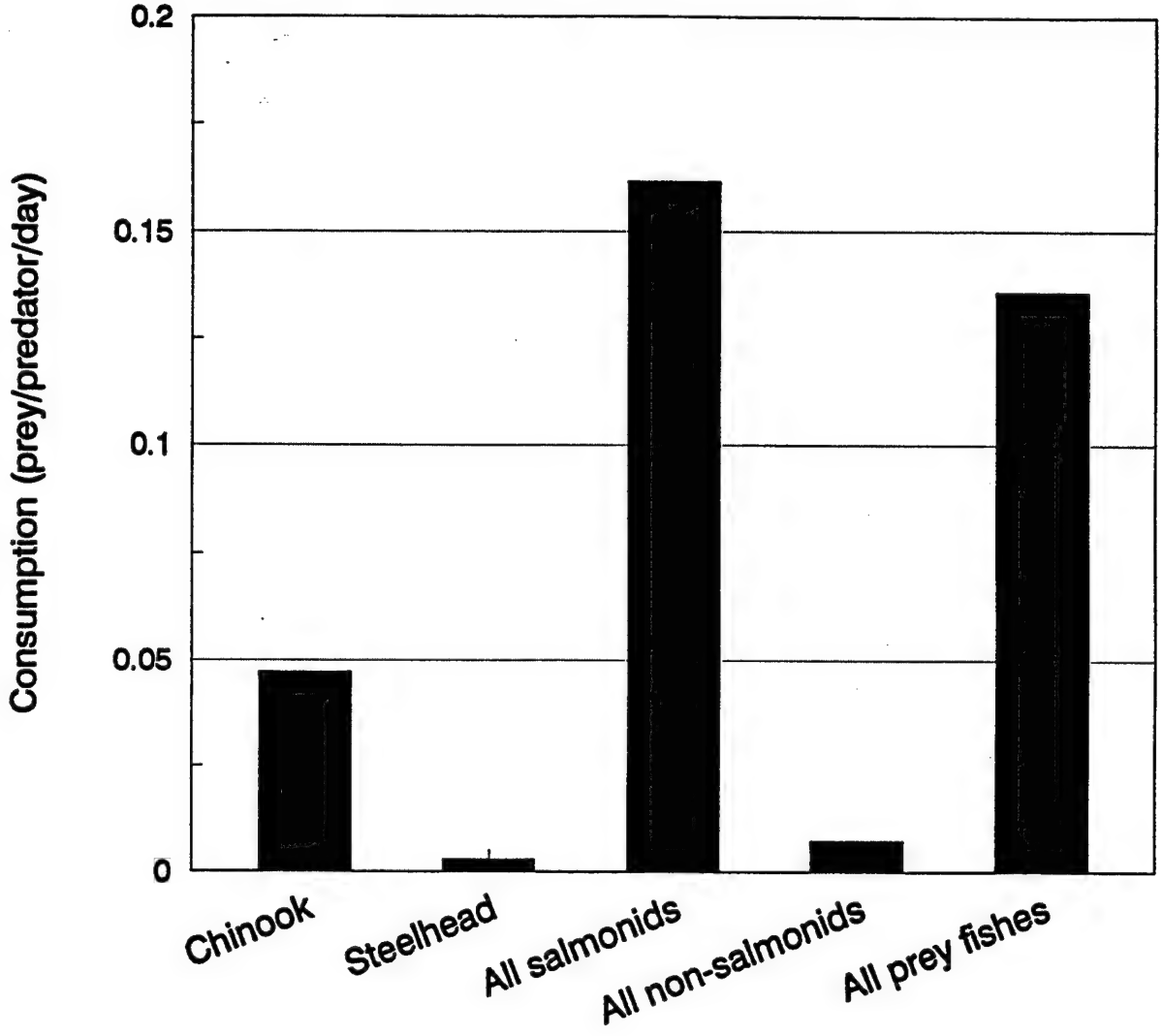


Figure 92. Consumption rates of fishes by northern squawfish in Lower Granite Reservoir, Idaho-Washington during April 1991.

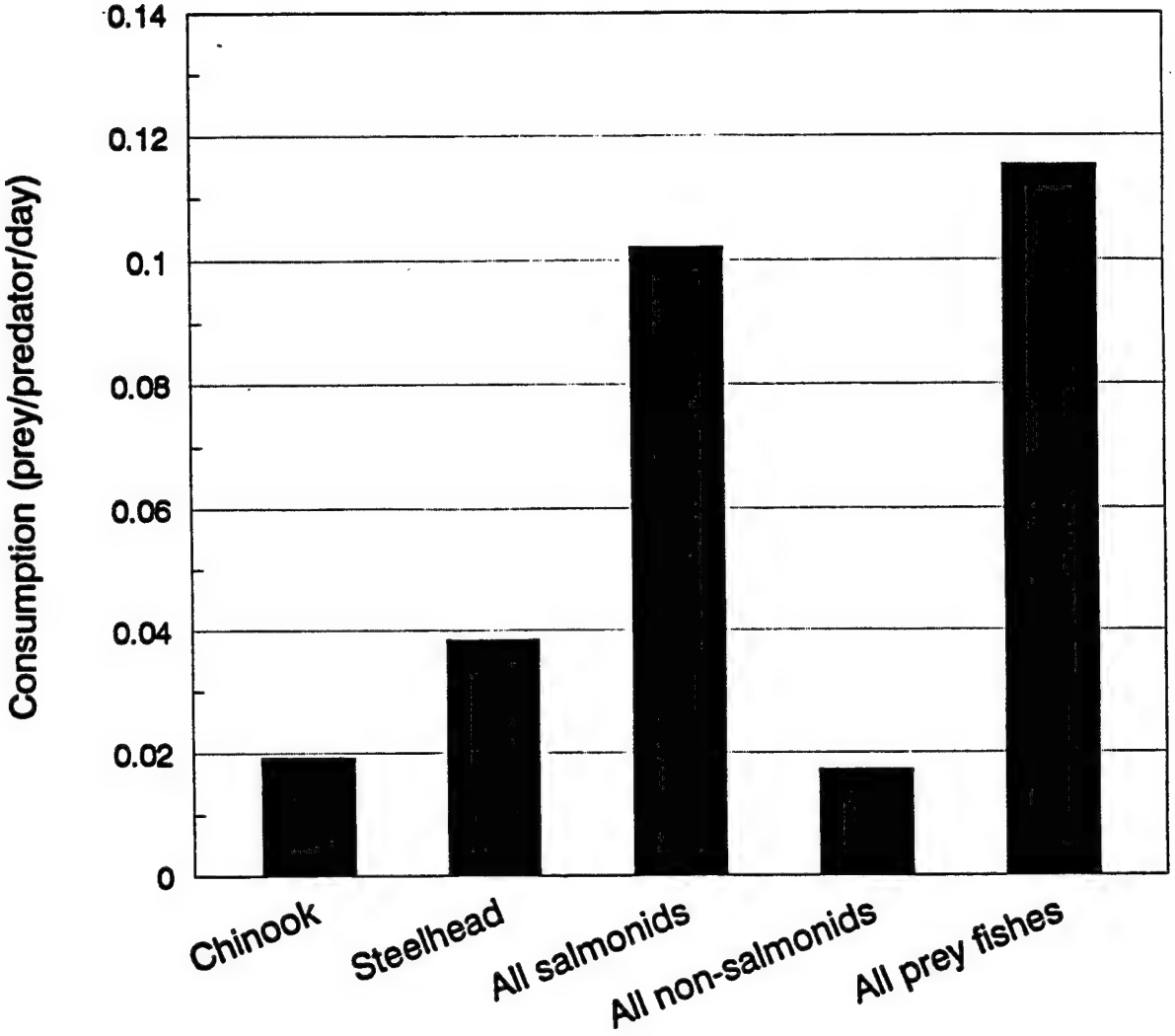


Figure 93. Consumption rates of fishes by northern squawfish in Lower Granite Reservoir, Idaho-Washington during May 1991.

non-salmonids (0.179 prey/predator/d; Figure 94). The second lowest mean monthly consumption rate of juvenile steelhead (0.0207 prey/predator/d) was during June. No consumption of chinook salmon was noted.

Based on comparison of catch/effort with similar gear types from John Day Reservoir (Beamesderfer and Rieman 1988), we used a population size of northern squawfish of 7,500 from RM 112.0 to RM 132.0 to estimate number of smolts consumed. Approximately 10,598 juvenile chinook and 630 juvenile steelhead were consumed by northern squawfish during April, whereas approximately 4,488 juvenile chinook and 8,928 juvenile steelhead were consumed in May. A total of approximately 4,658 steelhead were consumed in June. Combining these monthly estimates, the total loss by squawfish of juvenile chinook and steelhead during spring 1991 in Lower Granite Reservoir from RM 112.0 to RM 132.0 was 15,086 and 14,216, respectively. Combined losses for both identified and unidentified salmonids during spring 1991 was estimated at 67,076 salmonid smolts.

DISCUSSION

Northern squawfish sampled during 1991 were nearly identical in size to those sampled during 1990 for the presence of salmonids in their stomachs. Mean length was 390 mm in 1990 compared to 388 mm in 1991 (Bennett et al. 1993). The modal length class of squawfish was 350-400 mm for both years. Although the size of predators was similar between

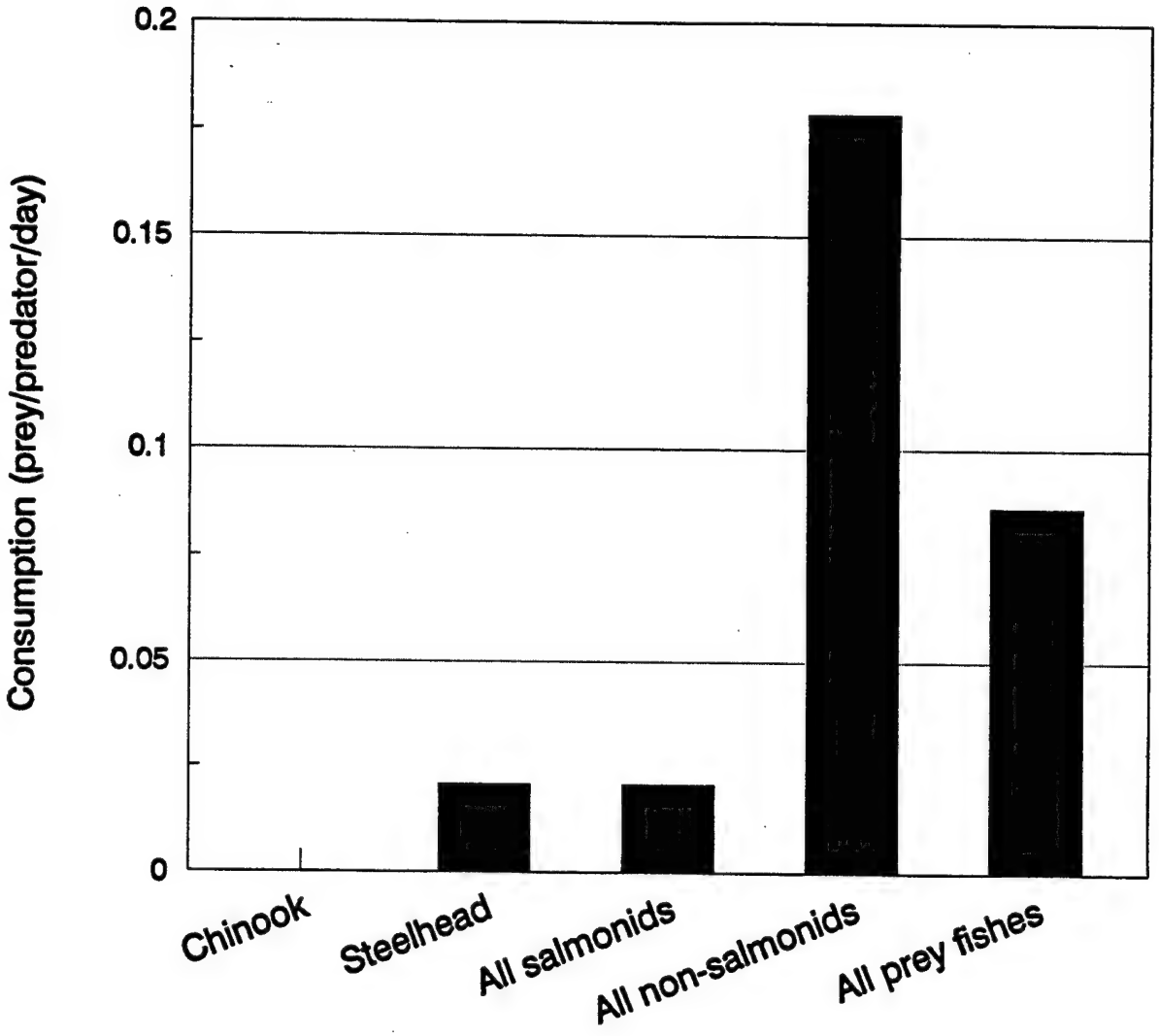


Figure 94. Consumption rates of fishes by northern squawfish in Lower Granite Reservoir, Idaho-Washington during June 1991.

1990 and 1991; substantial differences were found in overall consumption of salmonids.

Total daily ration of salmonids during April through June was substantially lower in 1991 than 1990, and the daily ration of chinook salmon and steelhead during 1991 was about 50% of that in 1990 (Bennett et al. 1993). However, the daily ration of all salmonids in 1991 was similar to that in 1990. Daily ration of chinook and steelhead were similar in 1990, whereas in 1991 ration of chinook was considerably higher compared to steelhead. Total daily ration for chinook in April 1990 was about 4.5 mg/g/d, whereas in April 1991 it was about 1 mg/g/d. The same trend between 1990 and 1991 was found in May. However in June 1990, daily ration of all salmonids was similar to that in June 1991.

Because of these differences in daily ration, our estimates of salmonid consumption by northern squawfish for 1991 were about 46% of that for 1990 (Bennett et al. 1993). We do not know the reason for differences in daily ration other than differences in flows through the reservoir. During 1990, a year of higher consumption, flows were generally < 70 kcfs through April, increased in early May, decreased in mid-May (40 kcfs) and increased (120 kcfs) substantially in early June. During 1991, flows remained below 60 kcfs in April, increased in mid-May to 80 kcfs and remained > 70 kcfs through June. The higher turbidities that ultimately result in Lower Granite Reservoir from higher discharges (Bennett and Shrier 1986) in 1991 may have contributed to lower estimates of salmonid consumption by northern squawfish.

Our estimates of consumption differ from those of Chandler (1992) for fish sampled in the same section of Lower Granite Reservoir. For example, Chandler (1992) estimated about 111,000 salmonids were consumed, while we estimated 67,000 salmonids. Though these differences seem large, only slight differences in data analysis are responsible. The northern squawfish that were used in both studies were the same fish and the contents were the same. Data analysis differences account for the differences in consumption. For example, Chandler (1992) used sizes of fish collected at Lower Granite Dam to identify whether the unknown fish in the stomach of squawfish was a chinook or steelhead smolt. We compared sizes of juvenile salmonids caught in the various collections (Objective 1) to those found in the stomachs of squawfish and then based our determination on that. Also, Chandler used a population density estimate of about 16,000 squawfish based on comparison of squawfish densities with those from John Day Reservoir (Beamesderfer et al. 1990), while ours was based on comparison of catch/effort with John Day Reservoir that provided an estimate of 7,500 squawfish. Although BPA's bounty program removed approximately 11,000 squawfish in 1992 throughout Lower Granite Reservoir, we suspect that the majority of these fish were collected outside of our study section. The total consumption differences are slight when the relatively low numbers of smolts consumed are compared to those released upstream and passing through this section of Lower Granite Reservoir.

Objective 4. To assess age-0 chinook salmon abundance in Lower Granite Reservoir and assess the potential suitability of the disposal sites for rearing of age-0 chinook salmon.

METHODS

Age-0 chinook were collected by beach seining during 1991 using identical methods employed for juvenile predator sampling (Objective 1). Areas of concentration of age-0 chinook were identified and measurements of macrohabitat characteristics were taken. Instantaneous growth calculations were made using:

$$G = \ln L_t - \ln L_o$$

where: $\ln l_t$ = natural log of length at time t and
$\ln l_o$ = Natural log of length (mm) at time of original capture.

RESULTS

A total of 299 age-0 chinook salmon were captured by beach seining between 4 April through 28 June, 1991. No age-0 chinook salmon were collected in littoral areas after 28 June, 1991. The highest catch/effort occurred on 27 May which suggests the highest abundance of age-0 chinook in Lower Granite Reservoir occurred during late May 1991.

The average length of age-0 chinook salmon generally increased throughout spring (Figure 95). Overall instantaneous growth calculations estimated growth at 0.50 mm/d between 4 April through 28 June. Mean lengths of juvenile chinook sampled in June ranged from 69-92 mm.

Ninety five percent of age-0 chinook (n = 284) were captured over substrates that consisted of > 75% fines (< 2 mm in diameter), whereas 100% of age-0 chinook (n = 299) were captured over substrates that consisted of > 75% fines and sand/cobble (< 50 mm in diameter; Figure

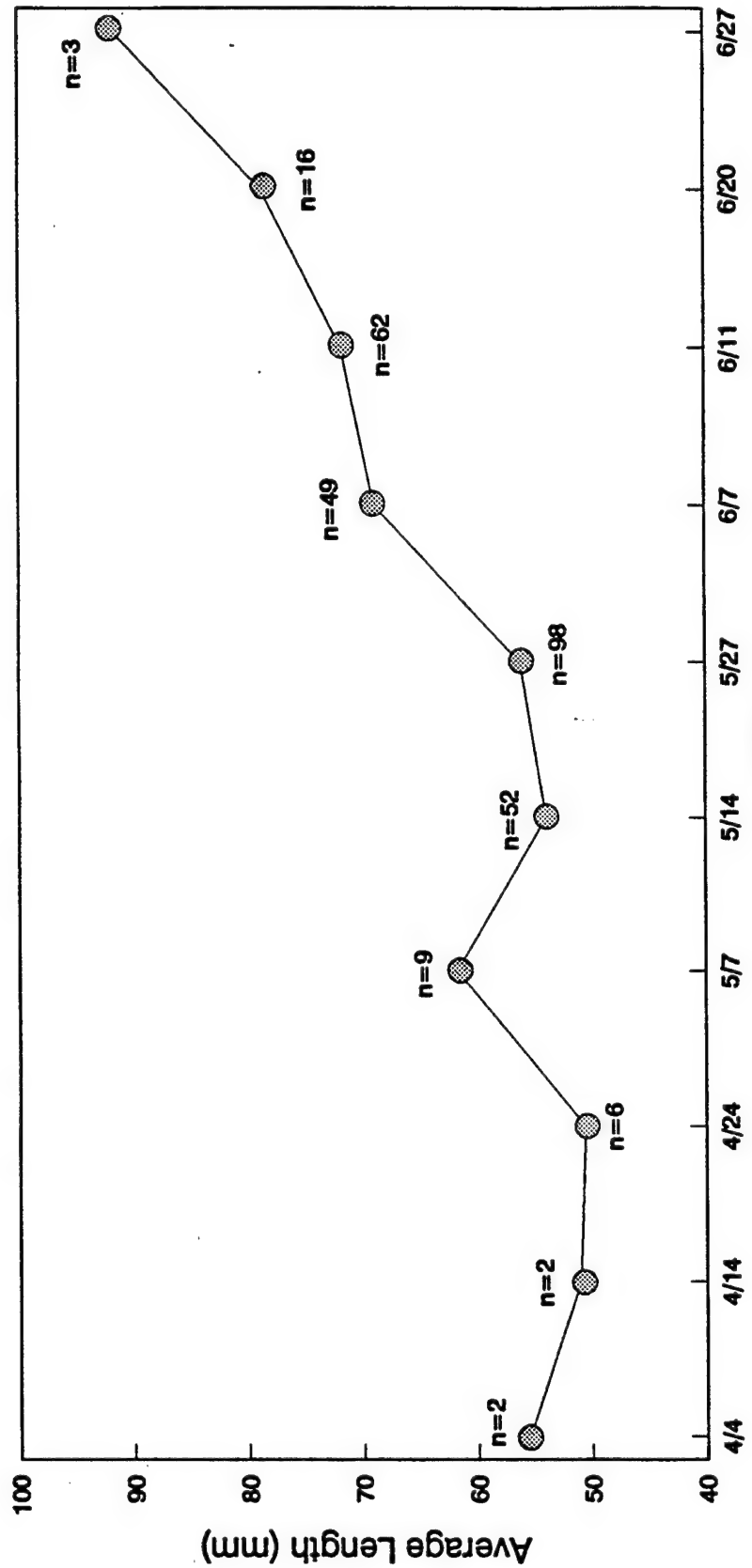


Figure 95. Mean total lengths of juvenile chinook salmon sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during spring-summer 1991.

96). During 1991, 2% of the age-0 chinook (n = 8) sampled were captured at shallow water disposal stations 1 and 2 (RM 120). Substrates at stations 1 and 2 consisted primarily of sands.

DISCUSSION

During 1991, our first collection of age-0 chinook was in early April and numbers generally increased along the shoreline of Lower Granite Reservoir into late May. Collections peaked on 27 May and decreased to a low of 3 age-0 chinook sampled on 27 June.

All age-0 chinook collected by beach seining in Lower Granite Reservoir were associated with either a sand (95%), sand/talus (2.3%), or sand/cobble substrate (2.7%; Figure 96). These sandy shorelines are almost exclusively the habitat where age-0 chinook salmon are collected and have been collected since 1985 (Bennett and Shrier 1985; Bennett et al. 1988, 1991, 1993). Sand and sand/cobble substrates are typically found in the upstream portion of Lower Granite Reservoir and were deposited as dredged material with construction of island disposal stations 1 and 2. Habitat created by island construction seems highly suitable for juvenile chinook, as 11% of the age-0 fish were collected at disposal stations 1 and 2 in 1990 (Bennett et al. 1993), although only 2% of the age-0 were collected at this site in 1991. We do not know why fewer age-0 chinook were collected from the island in 1991.

Lower recruitment to Lower Granite Reservoir may have occurred in 1991. Upstream habitats probably need to be saturated before age-0 chinook move downstream to the island. Based on the 1990 and 1991

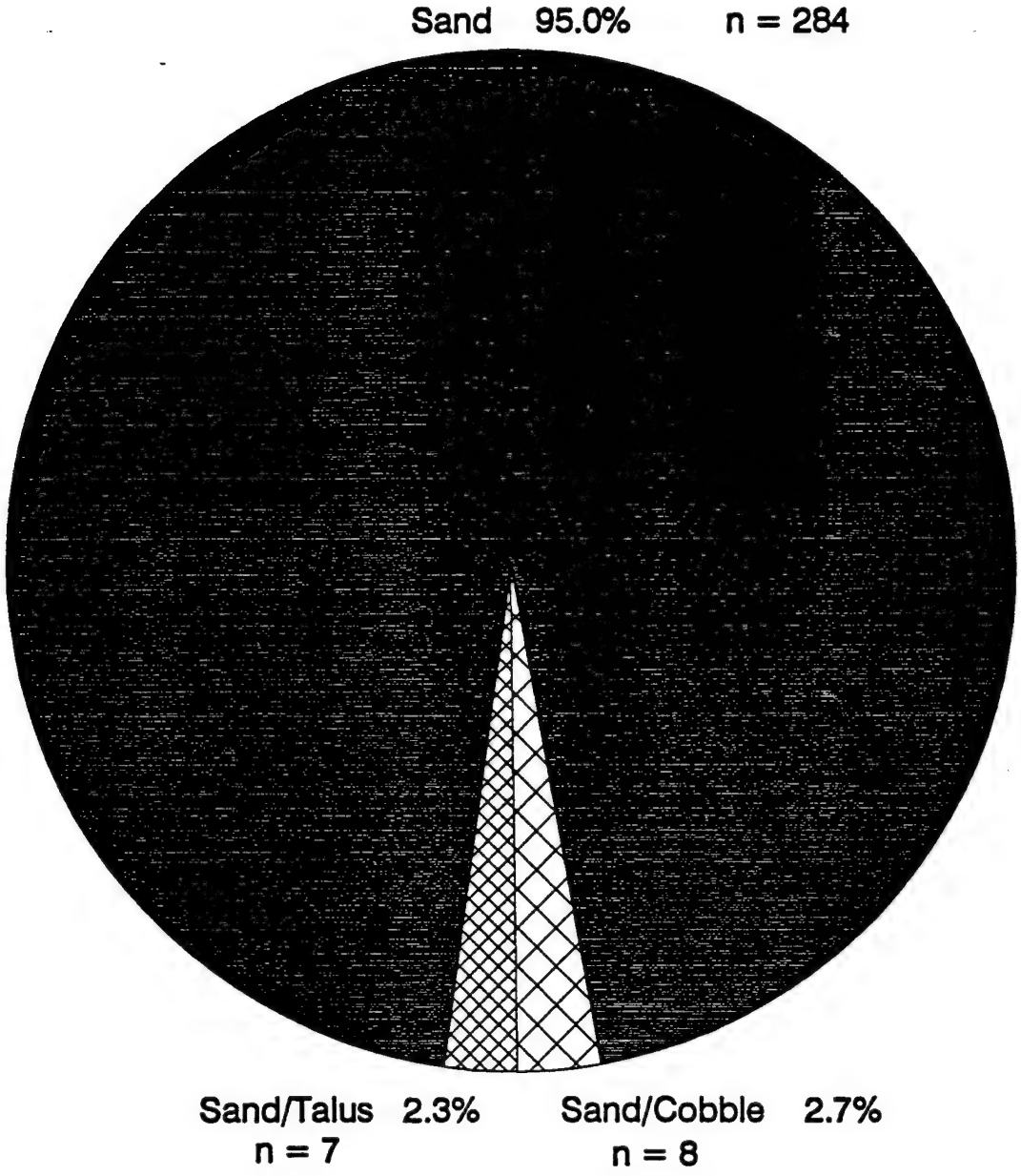


Figure 96. Habitat utilization and abundance of juvenile chinook salmon sampled by beach seining in Lower Granite Reservoir, Idaho-Washington during 1991.

collections, rearing habitat for age-0 chinook can be created by deposition of dredged materials. The suitability of the area seems to be adequate for rearing age-0 chinook salmon. However, higher numbers in upstream areas of Lower Granite Reservoir are probably necessary to saturate rearing habitats before age-0 chinook will rear in abundance at the island.

Objective 5. To compare benthic community structure and abundance at disposal and reference sites.

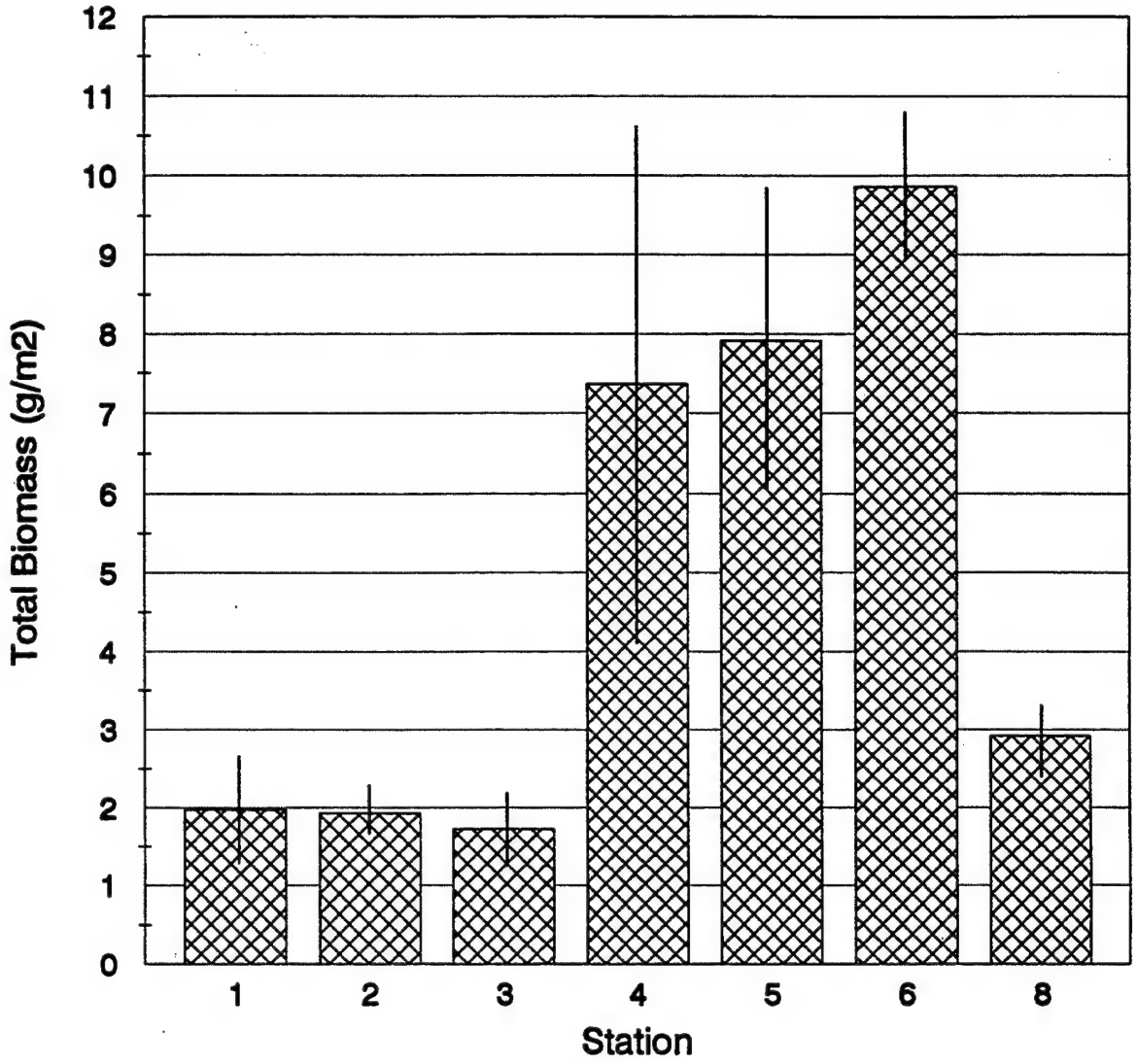
METHODS

A Shipek dredge (1,072.5 cm^2) was used to collect twelve benthic samples each at stations 1, 2, 3, 4, 5, 6 and 8 during September 1991. Four dredge hauls were taken along three evenly spaced transects at each station.

Benthic samples were washed through a 0.595 mm sieve bucket (#30) and immediately preserved in a 5% formalin solution. Organisms were separated into major taxonomic groups (Pennak 1987), enumerated and weighed in the laboratory. Wet weights were determined by blotting organisms for 1 to 3 minutes and weighed in a tared, water filled, covered vessel to preclude variations associated with evaporative water loss. Sample weights and numbers were expanded (x 9.32) for density (No/m^2) and standing crop (g/m^2) estimates.

RESULTS

Standing crop estimates of the benthic community sampled during 1991 ranged from 1.98 g/m^2 at shallow water disposal station 1 to 9.86 g/m^2 at mid-depth reference station 6 (Figure 97). Approximately 45% of the benthic community biomass was oligochaetes, while the remaining 55% was chironomids. The highest standing crop estimate of benthos was at mid-depth reference station 6 (9.86 g/m^2) followed by shallow water reference station 5 (7.92 g/m^2) and mid-depth disposal station 4 (7.36 g/m^2). Standing crop estimates of benthos at disposal stations 1 and 2 and shallow water reference station 3 were low and similar. Standing crop estimate at deep water reference station 8 was 2.92 g/m^2.



Station Comparison

6
5
4
8
1
2
3

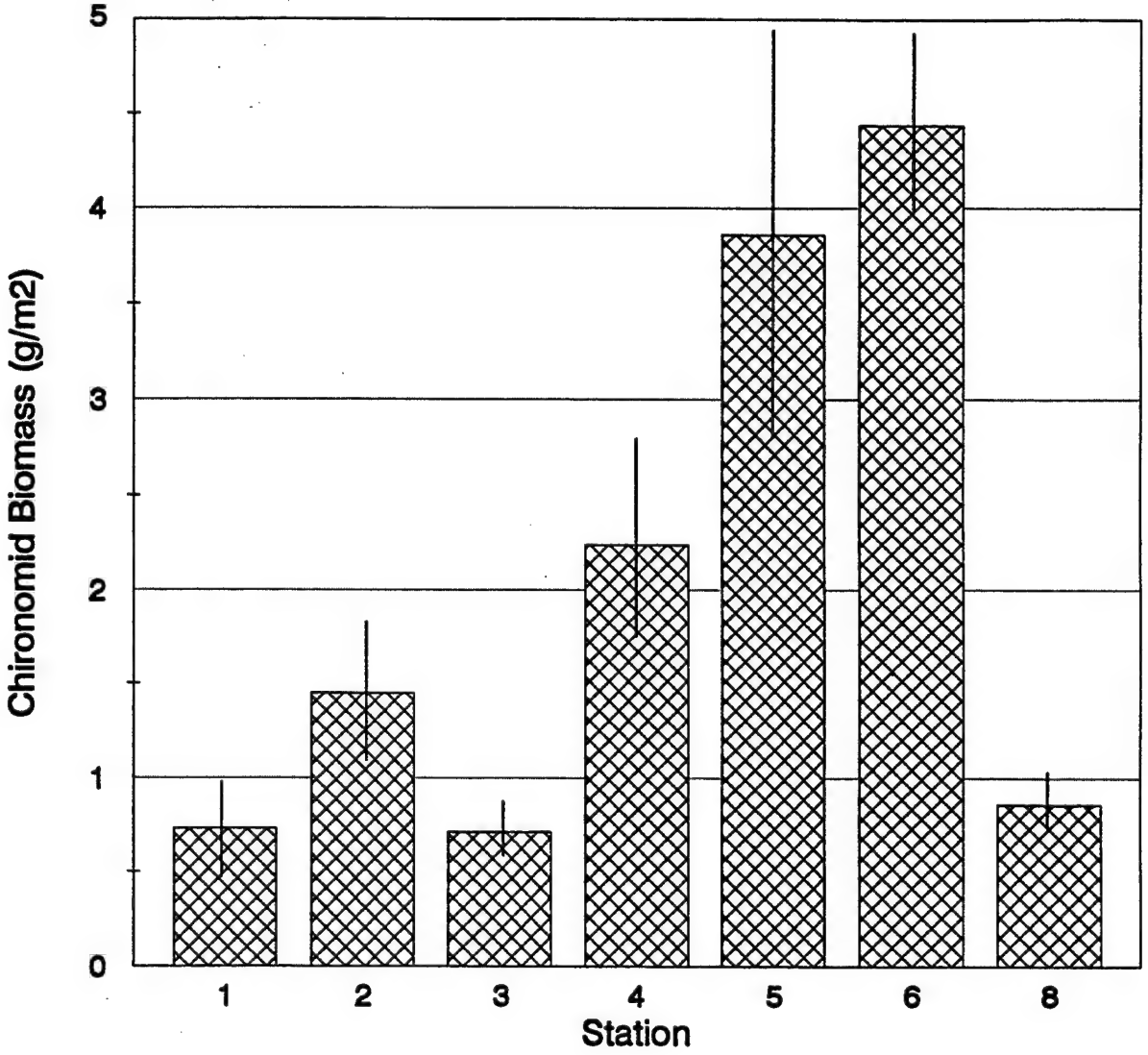
Figure 97. Standing crop estimates and statistical comparisons of total benthic biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations indicate statistical nonsignificance ($P > 0.05$).

Statistical differences in total benthic community biomass in 1991 among stations indicated reference stations 5 and 6 had significantly higher ($P < 0.05$) biomass than any other station (Figure 97). Benthic community biomass at disposal stations 1 and 2 was not significantly different from reference stations 8 and 3.

Standing crop estimates of chironomid biomass during 1991 ranged from 0.71 g/m^2 at shallow water reference station 3 to 4.4 g/m^2 at mid-depth reference station 6 (Figure 98). Chironomid biomass was highest at mid-depth (6) and shallow (5) water reference stations and mid-depth disposal station 4. The estimate of chironomid biomass at disposal station 1 were low and similar to estimates for shallow (3) and deep (8) water reference stations. The chironomid standing crop estimate at mid-depth disposal station 4 was 2.24 g/m^2.

Statistical differences in chironomid biomass during 1991 among stations were few (Figure 98). Chironomid biomass at reference stations 6 and 5 were significantly ($P < 0.05$) higher than other reference and disposal stations. Other significant differences among disposal and reference stations were not found.

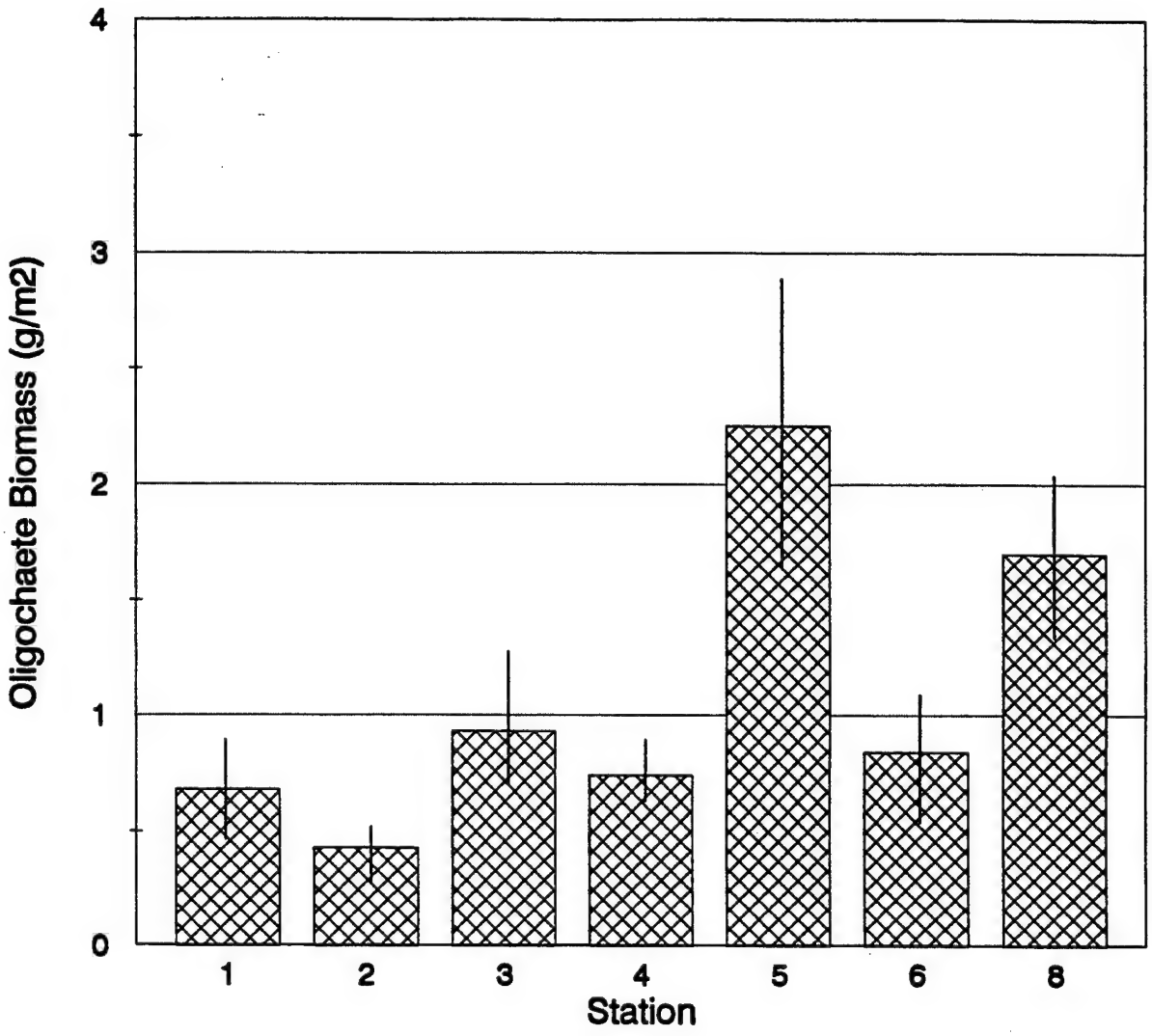
Oligochaete biomass during 1991 was highest at reference station 5 followed by reference station 8 (Figure 99). Standing crop estimates ranged from a high of 2.25 g/m^2 at reference station 5 to a low of 0.44 g/m^2 at disposal station 2. Statistically, oligochaete biomass at reference stations 5 and 8 were significantly higher than other reference and disposal stations (Figure 99).



Station Comparison

6
5
4
2
8
1
3

Figure 98. Standing crop estimates and statistical comparisons of chironomid biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations indicate statistical nonsignificance ($P > 0.05$).



Station Comparison

5
8
3
6
4
1
2

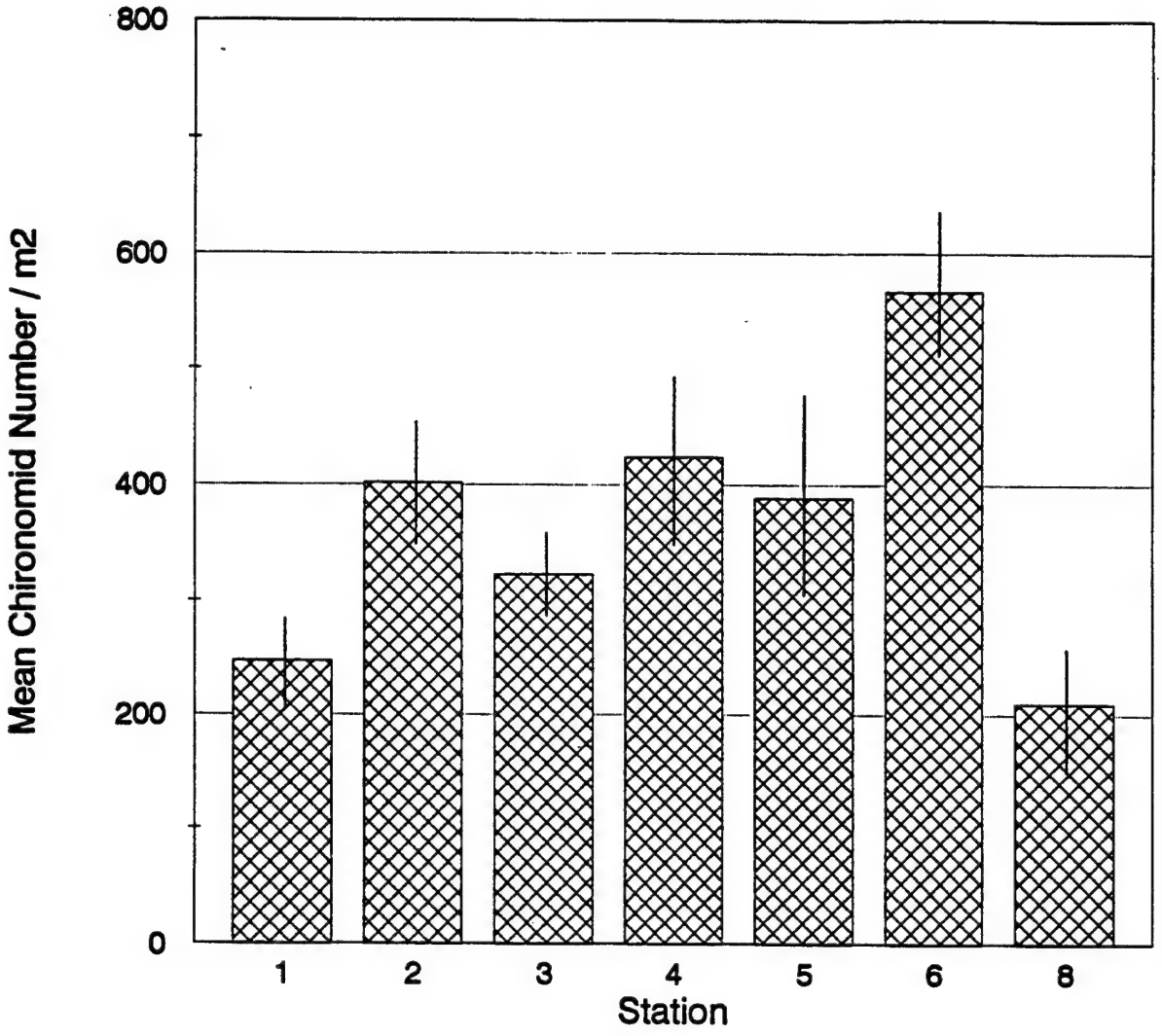
Figure 99. Standing crop estimates and statistical comparisons of oligochaete biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. The vertical line beside stations indicates statistical nonsignificance ($P > 0.05$).

Numerical density of chironomids was highest at reference station 6 (568/m^2) and lowest at reference station 8 (210/m^2; Figure 100). Densities of chironomids were statistically similar at disposal stations 4 and 2 and reference stations 6 and 5; these densities were significantly ($P < 0.05$) higher than those at stations 3, 8 and 1 (Figure 100).

1989 vs. 1991

Comparisons of benthic community standing crop estimates during 1989 and 1991 indicate general declines at all stations in Lower Granite Reservoir (Figure 101). During July 1989, standing crop estimates ranged from 1.43 g/m^2 at shallow water disposal station 2 to 13.3 g/m^2 at reference station 6 compared to 1.73 g/m^2 and 9.86 g/m^2 during September 1991, respectively. A substantial decrease in standing crop was between 1989 (9.66 g/m^2) and 1991 (2.92 g/m^2) at deep water reference station 8. Statistical ($P < 0.05$) differences in total benthic biomass between 1989 and 1991 were found at reference stations 6 and 8, as both were lower in 1991 (Figure 101).

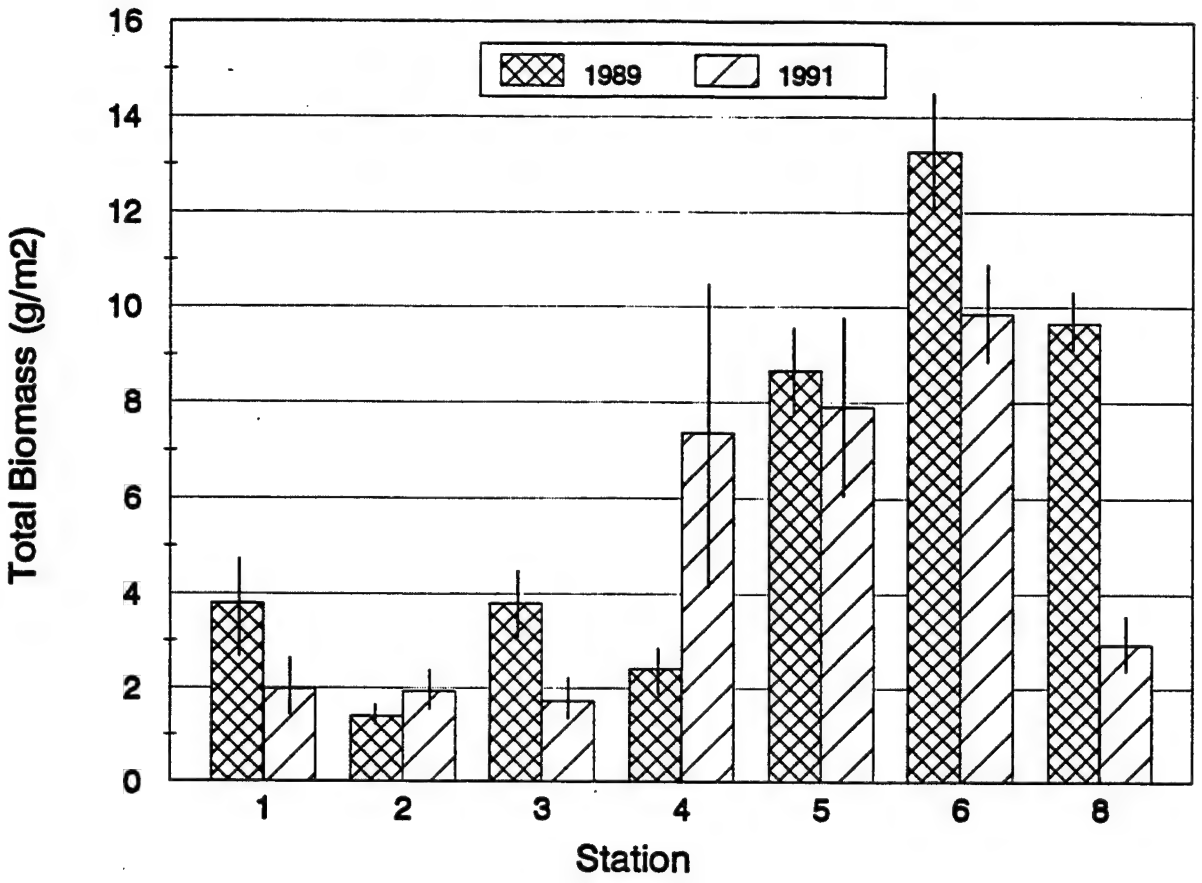
Comparisons of chironomid biomass from 1989 and 1991 showed increases at shallow (2) and mid-depth (4) disposal stations and shallow (5) and mid-depth (6) reference stations (Figure 102). The highest increase occurred at reference station 6 where the chironomid standing crop estimate increased from 2.5 g/m^2 in 1989 to 4.4 g/m^2 in 1991. Chironomid biomass at disposal station 1 decreased from about 3.13 g/m^2 in 1989 to 0.73 g/m^2 in 1991. Standing crop estimates of chironomids at



Station Comparison

6
4
2
5
3
1
8

Figure 100. Numerical densities and statistical comparisons of chironomids sampled in Lower Granite Reservoir, Idaho-Washington during 1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations indicate statistical nonsignificance ($P > 0.05$).



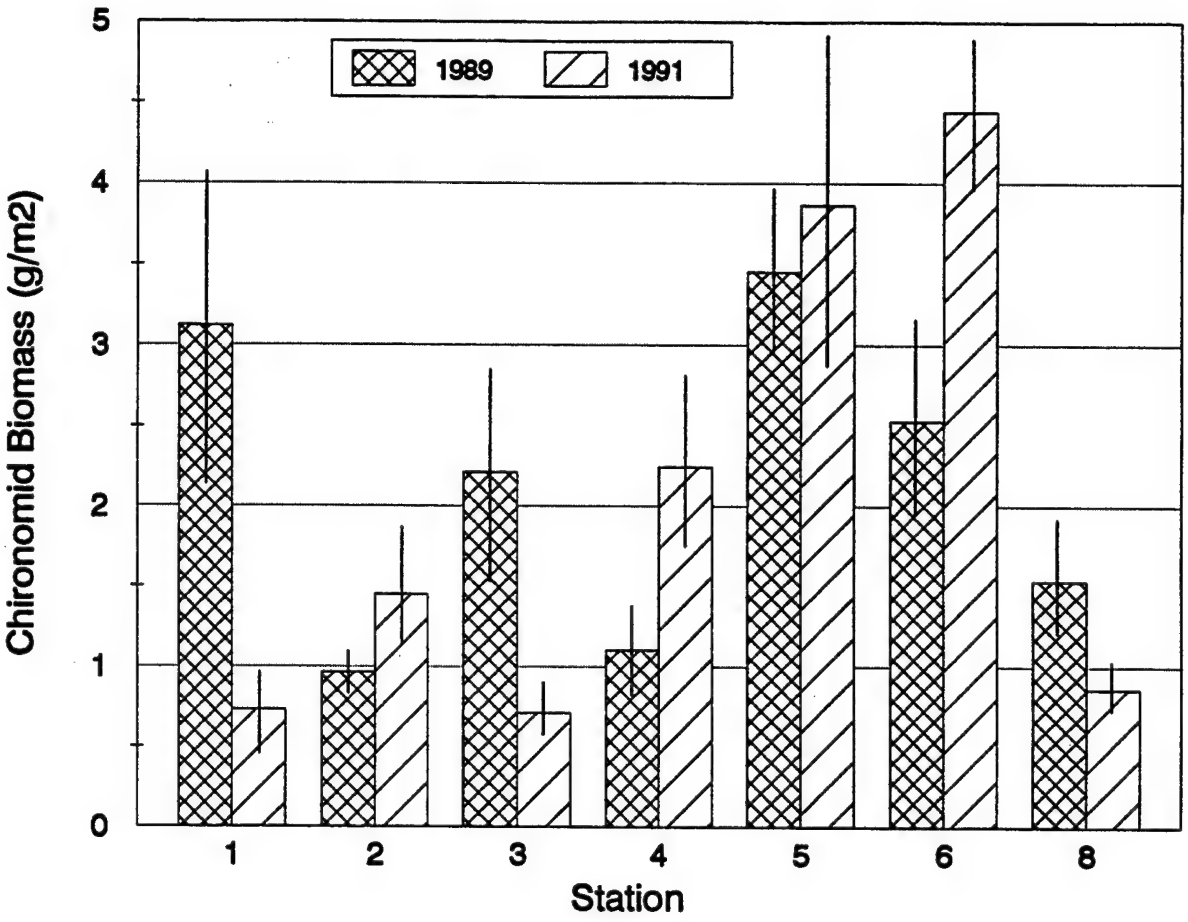
Station within Year Comparison

1989	1991
6	6
8 5	5
3	4 8
1	2
4	1
2	3

Year within Station Comparison

1	2	3	4	5	6	8
1989 1991	1991 1989	1989 1991	1991 1989	1989 1991	1989 1991	1989 1991

Figure 101. Standing crop estimates and statistical comparisons of total benthic biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).



Station within Year Comparison

1989	1991
5	6
1	5
6	4
3	2
8	8
4	1
2	3

Year within Station Comparison

1	2	3	4	5	6	8
1989	1991	1989	1991	1991	1991	1989
1991	1989	1991	1989	1989	1989	1991

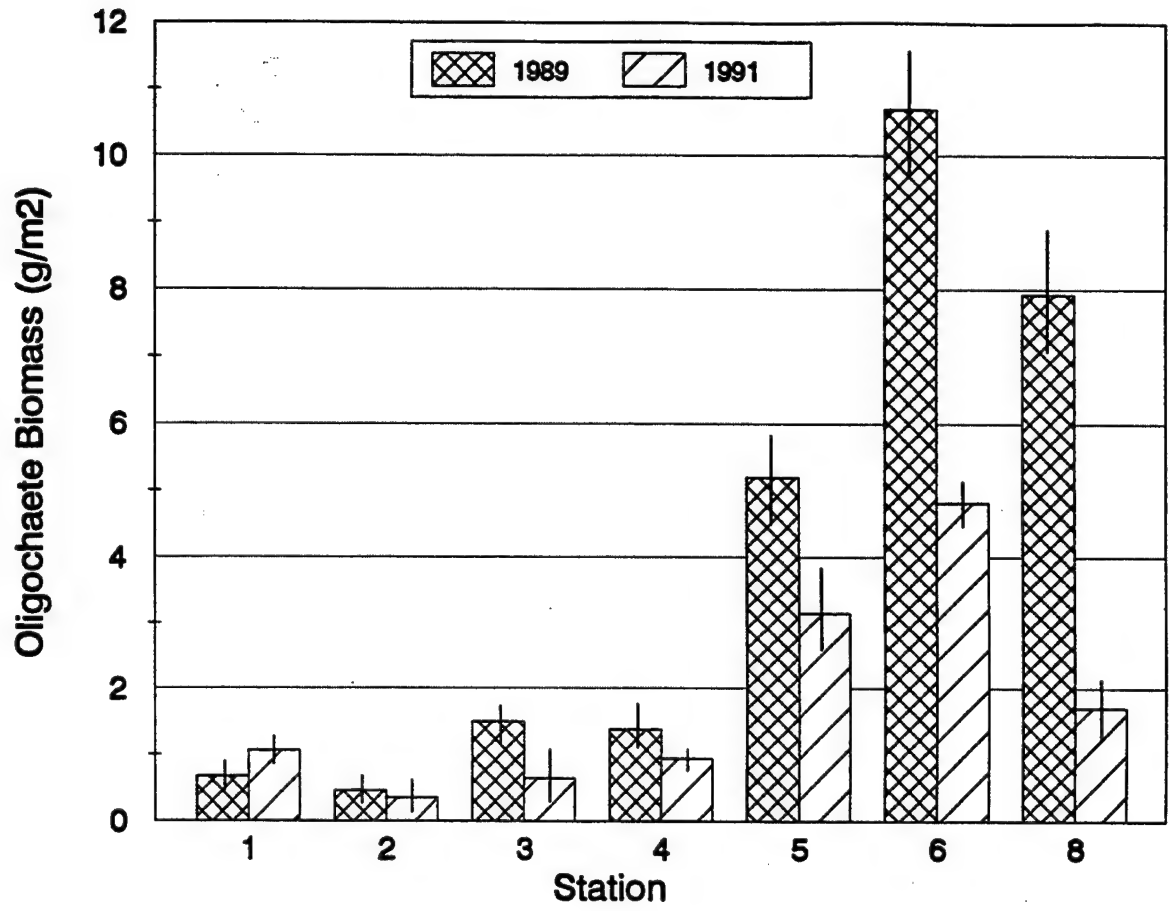
Figure 102. Standing crop estimates and statistical comparisons of chironomid biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).

shallow water disposal (1) and reference (3) stations and deep water reference station 8 decreased from 1989 to 1991.

Chironomid biomass was significantly ($P < 0.05$) higher in 1991 than 1989 at station 6, whereas chironomid biomass was higher or similar between 1989 and 1991 at other stations (Figure 102). Statistical differences in chironomid biomass between 1989 and 1991 were found at stations 1 and 6.

Oligochaete biomass during 1991 was generally low, but it followed a similar pattern between 1989 and 1991 (Figure 103). Oligochaete standing crop estimates at stations 1, 2, 3, 4 and 8 were generally less than 1 g/m^2 in 1989 and 1991. As with chironomids, station 6 had the highest standing crop estimate and disposal station 2 had the lowest during both 1989 and 1991. Mid-depth (6) and deep (8) water reference stations had the largest decreases in standing crop estimates from 1989 to 1991. The biomass of oligochaetes at reference station 6 decreased from 10.69 g/m^2 to 0.84 g/m^2 and station 8 decreased from 7.9 g/m^2 to 1.7 g/m^2. Oligochate biomass at reference station 6 was significantly ($P < 0.05$) higher than other reference and disposal stations in 1991 (Figure 103). Statistical differences in oligochaete biomass between 1989 and 1991 were found at reference stations 5, 6 and 8.

Comparisons of numerical density of chironomids for 1989 and 1991 indicated a general decrease at disposal (1 and 2) and reference (3, 5, 6 and 8) stations (Figure 104). The only increase in chironomid density was at disposal station 4 from 266/m^2 in 1989 to 425/m^2 in 1991, although this difference was not statistically ($P > 0.05$) significant



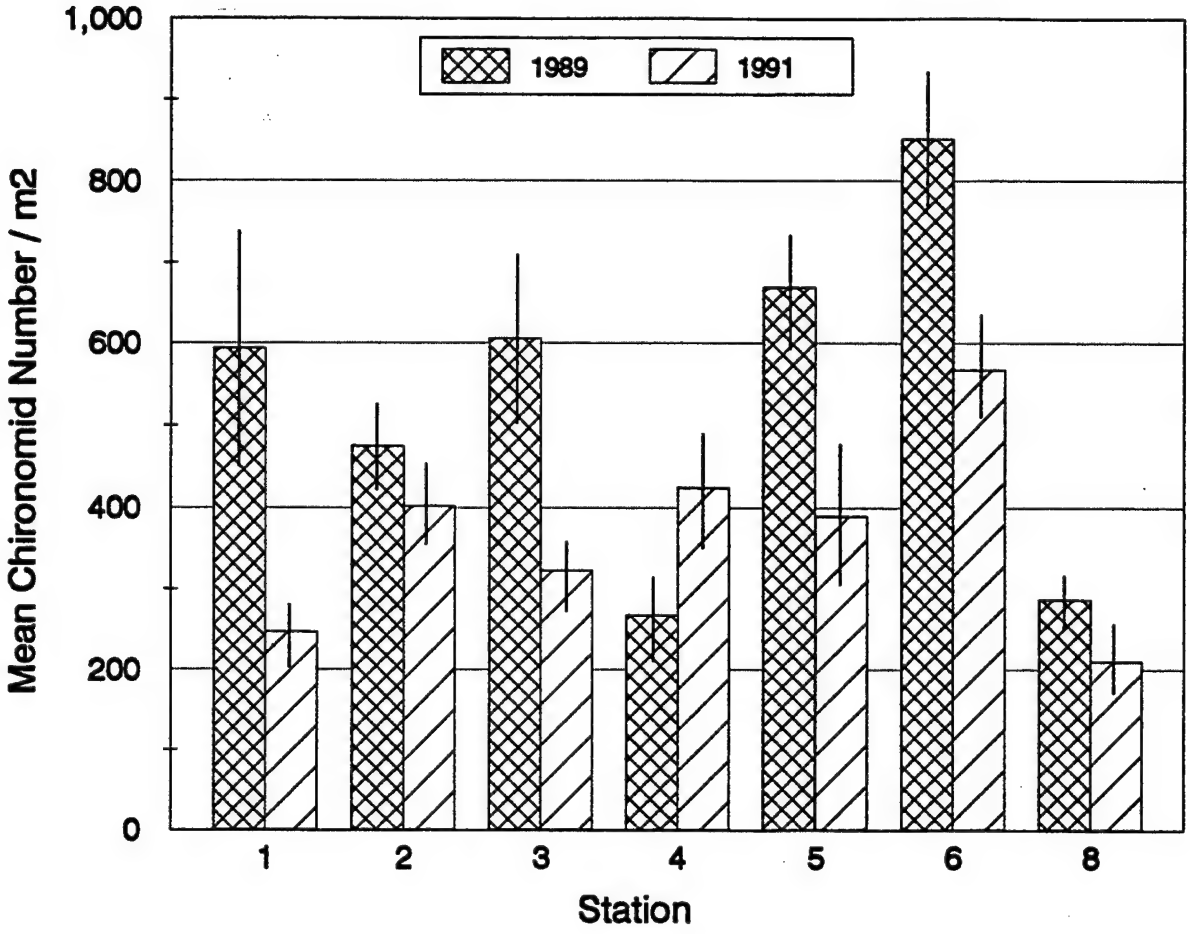
Station within Year Comparison

1989	1991
6	6
8	5
5	8
3	1
4	4
1	3
2	2

Year within Station Comparison

1	2	3	4	5	6	8
1991	1989	1989	1989	1989	1989	1989
1989	1991	1991	1991	1991	1991	1991

Figure 103. Standing crop estimates and statistical comparisons of chironomids sampled in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Vertical lines on the bars indicate 95% confidence interval around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).



Station within Year Comparison

1989	1991
6	6
5	4
3	2
1	3
2	5
8	1
4	8

Year within Station Comparison

1	2	3	4	5	6	8
1989	1989	1989	1991	1989	1989	1989
1991	1991	1991	1989	1991	1991	1991

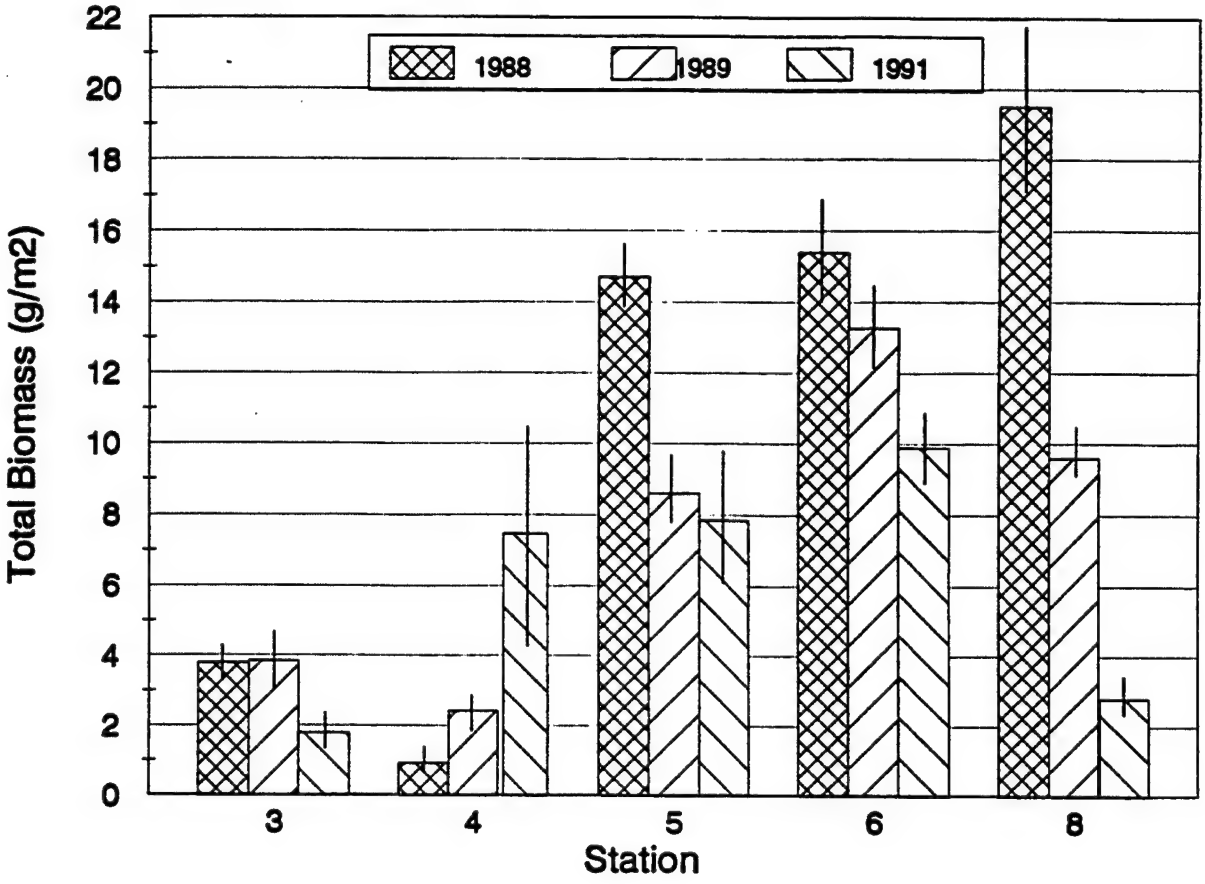
Figure 104. Numerical densities and statistical comparisons of chironomids sampled in Lower Granite Reservoir, Idaho-Washington during 1989-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).

(Figure 104). Numerical densities of chironomids were statistically similar at disposal stations 2 and 4 and reference station 8, whereas numerical densities of chironomids showed a significant ($P < 0.05$) decrease between 1989 and 1991 at disposal (1) and reference (3, 5 and 6) stations.

1988 vs. 1989 vs. 1991

Overall changes in benthic community biomass between 1988, 1989 and 1991 suggested a decrease at most stations, except at disposal station 4 where biomass increased (Figure 105). The largest decrease from 1988 to 1991 was at deep water reference station 8. Total biomass increased at station 4 from about 1 g/m^2 in 1988 to 7.37 g/m^2 in 1991. Statistical differences in benthic community standing crop estimates among 1988, 1989 and 1991 were found at reference stations 5 and 8 (Figure 105). Standing crop estimates were similar at both of these stations where biomass was highest in 1988 followed by 1989 and 1991. From the time of disposal in 1988 to post disposal in 1991, the benthic community biomass increased at disposal station 4, however the increase was not significant ($P > 0.05$). Few other differences in total benthic community biomass were found.

Chironomid biomass increased slightly at disposal station 4 and was generally similar at mid-depth reference station 6 from 1988 to 1991 (Figure 106). Chironomid biomass at reference station 5 dropped substantially from 1988 to 1989 and remained similar in 1991. Deep water reference station 8 decreased in chironomid standing crop from



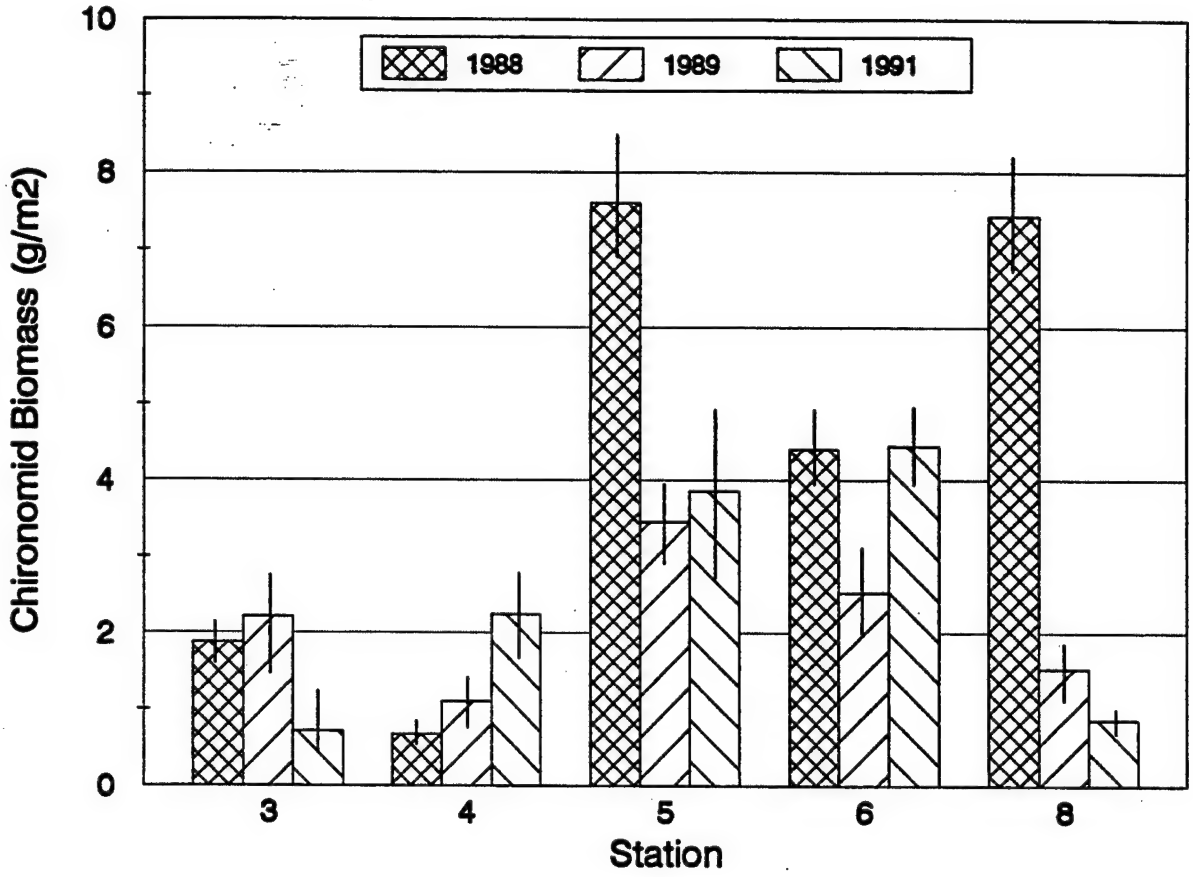
Station within Year Comparison

1988	1989	1991
8	6	6
6 5	8 5	8 5
3 4	3 4	4 3

Year within Station Comparison

3	4	5	6	8
1989	1991	1988	1988	1988
1988	1989	1989	1989	1989
1991	1988	1991	1991	1991

Figure 105. Standing crop estimates and statistical comparisons of total benthic biomass sampled in Lower Granite Reservoir, Idaho-Wasington during 1988-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).



Station within Year Comparison

1988	1989	1991
5	5	6
8	6	5
6	3	4
3	8	3
4	4	8

Year within Station Comparison

3	4	5	6	8
1989	1991	1988	1988	1988
1988	1989	1991	1991	1989
1991	1988	1989	1989	1991

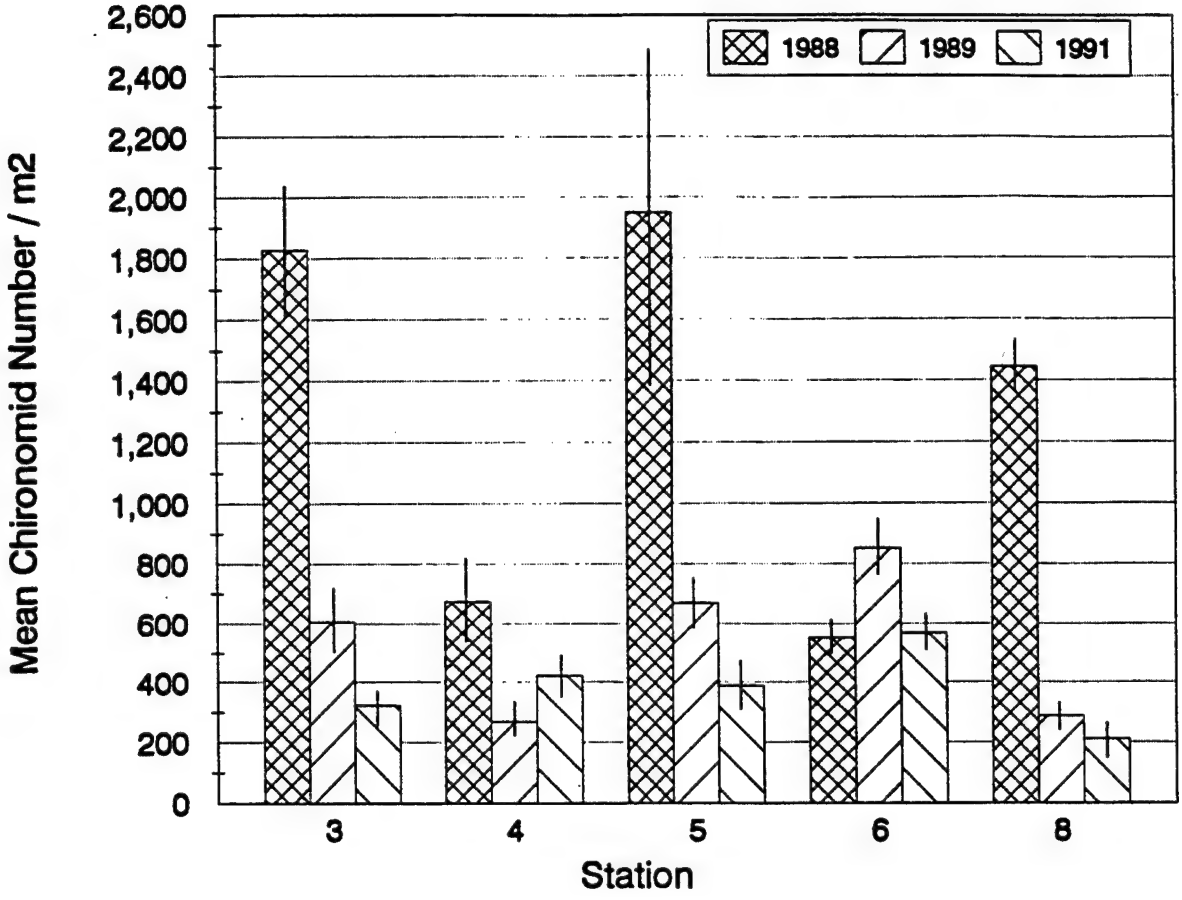
Figure 106. Standing crop estimates and statistical comparisons of chironomid biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).

7.44 g/m^2 in 1988 to 0.87 g/m^2 in 1991. Decreases in chironomid biomass from 1988 were significant ($P > 0.05$) at reference stations 5, 6 and 8. Standing crop estimates of chironomids at station 3 declined, while those at station 6 declined in 1989 and were similar between 1988 and 1991 (Figure 106). Chironomid standing crop at disposal station 4 increased from 0.67 g/m^2 in 1988 to 2.24 g/m^2 in 1991.

Comparisons of numerical density of chironomids from 1988, 1989 and 1991 at disposal (4) and reference (3, 5 and 8) stations decreased (Figure 107). The highest decrease occurred at reference station 5 where numbers changed from 1,949/m^2 in 1988 to 390/m^2 in 1991. Densities of chironomids were generally similar at reference station 6 and disposal station 4 between 1988, 1989 and 1991. Differences in chironomid density from 1988, 1989 and 1991 were significant at reference station 5 and 8 (Figure 107).

Comparison of oligochaete standing crop estimates for 1988, 1989 and 1991 showed a general decline at all stations (Figure 108). The largest decrease in standing crop estimates of oligochaetes occurred at mid-depth (6) and deep water (8) reference stations. Statistically, differences in oligochaete biomass at stations 5, 6 and 8 were significant (Figure 108). At reference station 8, oligochaete biomass declined significantly since 1988.

Oligochaetes were counted but we have opted not to express density or numerical abundance. Because of their propensity to fragment, variation in numbers of oligochaetes among sorters would not provide a meaningful comparison.



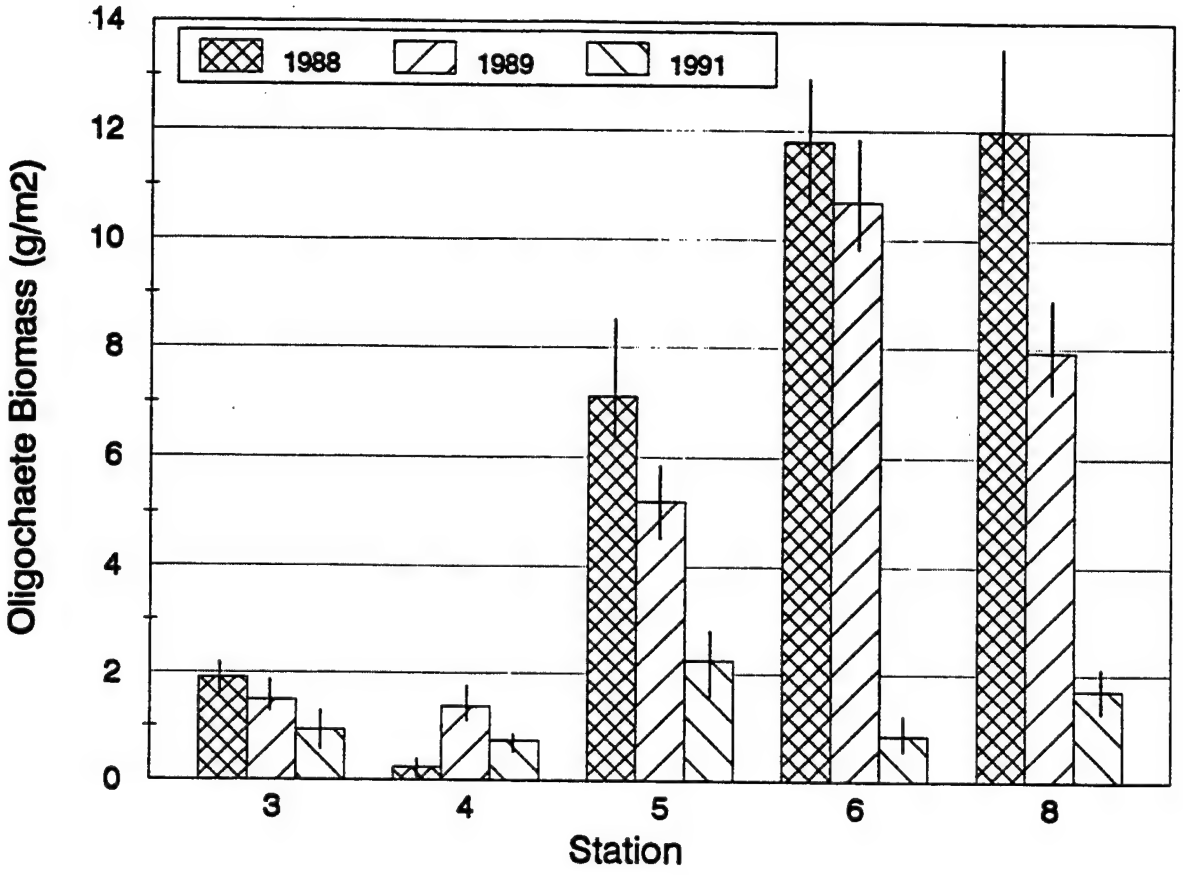
Station within Year Comparison

1988	1989	1991
5	6	6
3	5	4
8	3	3
4	8	5
6	4	8

Year within Station Comparison

3	4	5	6	8
1988	1988	1988	1989	1988
1989	1991	1989	1988	1989
1991	1989	1991	1991	1991

Figure 107. Numerical densities and statistical comparisons of chironomids sampled in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).



Station within Year Comparison

1988	1989	1991
8	6	6
6	8	5
5	5	8
3	3	4
4	4	3

Year within Station Comparison

3	4	5	6	8
1988	1989	1988	1988	1988
1989	1991	1989	1989	1989
1991	1988	1991	1991	1991

Figure 108. Standing crop estimates and statistical comparisons of oligochaete biomass sampled in Lower Granite Reservoir, Idaho-Washington during 1988-1991. Vertical lines on the bars indicate 95% confidence intervals around the mean. Vertical lines beside stations and years indicate statistical nonsignificance ($P > 0.05$).

DISCUSSION

Changes in the benthic community in Lower Granite Reservoir are of utmost interest to fisheries managers because of the importance of food for juvenile salmonids rearing and migrating through the reservoir. Our data from 1991 corroborate our previous findings that the benthic community in Lower Granite Reservoir is relatively simple as it is composed of predominantly oligochates and chironomids (Bennett and Shrier 1986; Bennett et al. 1991; Curet, Unpublished data). Earlier research on food items of salmonid smolts in Lower Granite Reservoir demonstrated the importance of chironomid larvae to salmonid smolts (Bennett and Shrier 1986; Bennett et al., Unpublished data; Curet, Unpublished data).

Chironomid biomass generally decreased in 1991 from 1988 and 1989 in Lower Granite Reservoir. One exception was mid-depth disposal station 4 which showed an increase in chironomid biomass. Otherwise, standing crop estimates of chironomids declined. For example, mean standing crop at reference station 8 decreased from 7.6 g/m^2 in 1988 to < 1 g/m^2 in 1991. We can not explain this apparent substantial decrease in chironomid standing crop estimates.

The general decrease in standing crop estimates of chironomids was similar to decreases in chironomid density. The most significant decreases in density occurred at reference station 5 when in 1988 density was 1,950/m^2 compared to 300/m^2 in 1991. As with standing crop estimates, numerical density of chironomids increased from 1988 to 1991 at disposal station 4.

Oligochaete biomass also exhibited a similar decline in Lower Granite Reservoir from 1988 to 1991, with the exception of disposal station 4. As with chironomid biomass, the largest decline in oligochaete biomass occurred at reference station 8 from 1988 to 1991.

Oligochaetes were counted, but because of their tendency to break during sieving and counting, we do not believe count data are precise.

The overall decrease in benthic community biomass in Lower Granite Reservoir can not be explained. The variation observed may be natural or possibly a response to temperature changes that occurred as a result of cool water releases from Dworshak Reservoir during August 1991 (Karr et al. 1991). We know of no other perturbation that could have affected the benthic community during 1991. Comparative data collected in 1992 will help explain the apparent changes in the benthic community in Lower Granite Reservoir.

The increase in oligochaete and chironomid biomass and chironomid density and disposal station 4 suggests that the benthic community has required at least four years to become similar to other reference areas. We cannot determine whether the community is stable or will increase further from its present level. Sampling in 1992 will provide additional data on the changes in benthos at this mid-depth station converted to shallow water.

OVERALL DISCUSSION

Results from year-4 sampling indicated changes seem to be occurring in the Lower Granite Reservoir benthic community. Oligochaetes and chironomids continue to dominate the benthos in soft substrates as was first observed in 1985 (Bennett and Shrier 1986). One of the more significant changes possibly affecting the numbers of fish is the overall decrease in abundance of chironomids, oligochaetes and all benthos compared to 1988 and 1989. Some decreases in benthos at the sampling stations were substantial, especially those at reference stations 6 and 8. However, one interesting aspect of benthic community monitoring is the increase at disposal station 4. Benthic community abundance has been low at disposal station 4 since the deposition of dredged material in 1988. In 1991 chironomid standing crops increased in abundance compared to 1989 and 1988 (Bennett et al. 1991; Figure 106). Although these increases were not statistically ($P > 0.05$) different, the higher standing crop suggests a possible recovery from the deposition of dredged material (Figure 106). Increases in chironomid biomass at disposal station 4 are probably related to the accumulation of organic matter on the substrate as the underwater plateau ages. Deposition of about 2 inches of fines occurs annually (Les Cunningham, Army Corps of Engineers, Walla Walla, WA., Personal Communication) which seem to be high in organic matter that provides food for chironomids. Overall increases in total biomass were also observed at station 4 in 1991 over those measured in 1988 and 1989 (Figure 105). However, like the chironomid biomass, these too were not

significant. Our data from 1991 suggests further increases in benthic community biomass at station 4, and possibly the island disposal stations, may occur in the future. To date, we have observed a slight decrease in benthos at station 1 since 1989 and a slight increase at station 2.

As indicated earlier, we have observed few changes in the fish community since we first began monitoring in Lower Granite Reservoir during 1985 (Bennett and Shrier 1986). The major change seems to be an increase in smallmouth bass and a decrease in nongame species such as redside shiners and chiselmouths. We believe the decrease in abundance of nongame species may be a possible maturation of the fish community and changes associated with general habitat conditions. The decrease in abundance of chiselmouth and redside shiners may be a response to the ageing of the reservoir. However, they may have increased in abundance after impoundment and are now decreasing. Both of these species were highly abundant in Little Goose Reservoir in 1979 and 1980, especially in the tailwater (Bennett et al. 1983).

Changes in relative abundance of fishes in Lower Granite Reservoir may be associated with reservoir ageing. Kimmel and Groeger (1986) reported that the biological productivity of reservoirs change with reservoir age although few analyzes have been conducted. Jenkins (1967) found that clupeid standing crop increased with ageing of a southeast reservoir. Additionally, Jenkins and Morais (1971) found that reservoir age was negatively correlated with sport fish harvest, although < 5% of the variation in the regression equations was accounted for in black

bass and sunfish harvest. However, no Columbia River system reservoirs were included in these analyses and we do not know how representative these relationships are to Lower Granite Reservoir.

We do not believe that increased abundance of smallmouth bass can be attributed to the in-water disposal activities. Increased abundance of smallmouth bass may be a response to more suitable habitat conditions for spawning and rearing associated with increasingly stable water levels and decreased flows during the last five years. These changes would favor smallmouth bass spawning success, growth, over-wintering mortality and ultimately recruitment. Fluctuating water levels have been observed to adversely affect spawning success of centrarchid fishes throughout North America and in Little Goose Reservoir (Bratovich 1985). Sallee (1991) reported that smallmouth bass abundance was inversely related to discharge in Illinois.

We observed smallmouth bass spawning along the shoreline at station 2 of Centennial Island. Perhaps the armoring on the channel side of the island, placed to alleviate erosion, provides suitable habitat for spawning. The wave action and faster velocities keep the substrate clean which may enhance its attractiveness as a spawning site. The few number of spawning nests observed along this section of the island, however, probably do not account for the apparent total population increase in the reservoir, although larger cobble on the shoreline of the island is sparse throughout the middle part of the reservoir.

Although we have continued to monitor the abundance of northern squawfish, we have not observed any long-term changes in population abundance that could be correlated with the deposition of dredged material in Lower Granite Reservoir. During 1991, we found the principal location for squawfish rearing was in the upstream portion of the reservoir (station 11; RM 135.0). Although similar habitat is widely available in down reservoir areas, including the island, we have not found high abundance of larval squawfish at any of the disposal stations. One key question is the actual population abundance of northern squawfish in Lower Granite Reservoir. This is especially important as the number of squawfish has a major effect on the smolt consumption estimate for the reservoir. Although a number of squawfish population estimates have been used to estimate smolt consumption in Lower Granite Reservoir, ranging from 15,000 (Chandler 1992) to 7,500 (Bennett et al. 1993), all consumption estimates suggest less than 200,000 smolts are being consumed by northern squawfish in the 20-mile section of Lower Granite Reservoir (approximately RM 112-132) that we sampled. A better estimate of population abundance should be available in fall 1993, as it is one focus of the predator sampling for 1993 (Bennett, Unpublished data). Also, Chandler and Bennett (Unpublished data) are currently assessing confidence intervals around the estimate of smolt consumption.

One highly informative aspect of this study has been the assessment of abundance and distribution of white sturgeon in Lower Granite Reservoir. Our estimate of white sturgeon throughout Lower

Granite Reservoir of about 1,400 fish seems to be realistic based on the confidence intervals and the similarity of estimates between 1990 and 1991. Another interesting aspect of our sturgeon assessment has been the similarities in habitat use from year to year with slight changes associated with various flow regimens. Our sampling in 1990 and 1991 has shown that the upstream portion of Lower Granite Reservoir is the most critical portion of the reservoir for sturgeon rearing. Sampling to date indicates white sturgeon abundance in the lower reservoir is low. If deep-water sediment disposal were the selected alternative to alleviate the sediment deposition problem around the confluence, our sampling strongly suggests that white sturgeon would likely not be impacted. The importance of depth > 60 ft (> 18.2 m) has not been found and abundance of sturgeon is relatively low in that section of the reservoir. Intensive sampling is planned downstream of RM 120 during 1993. The area adjacent to Knoxway Bay continues to be a concentration area for sturgeon in the spring and our 1993 sampling should determine if other areas of concentration occur in the lower part of the reservoir.

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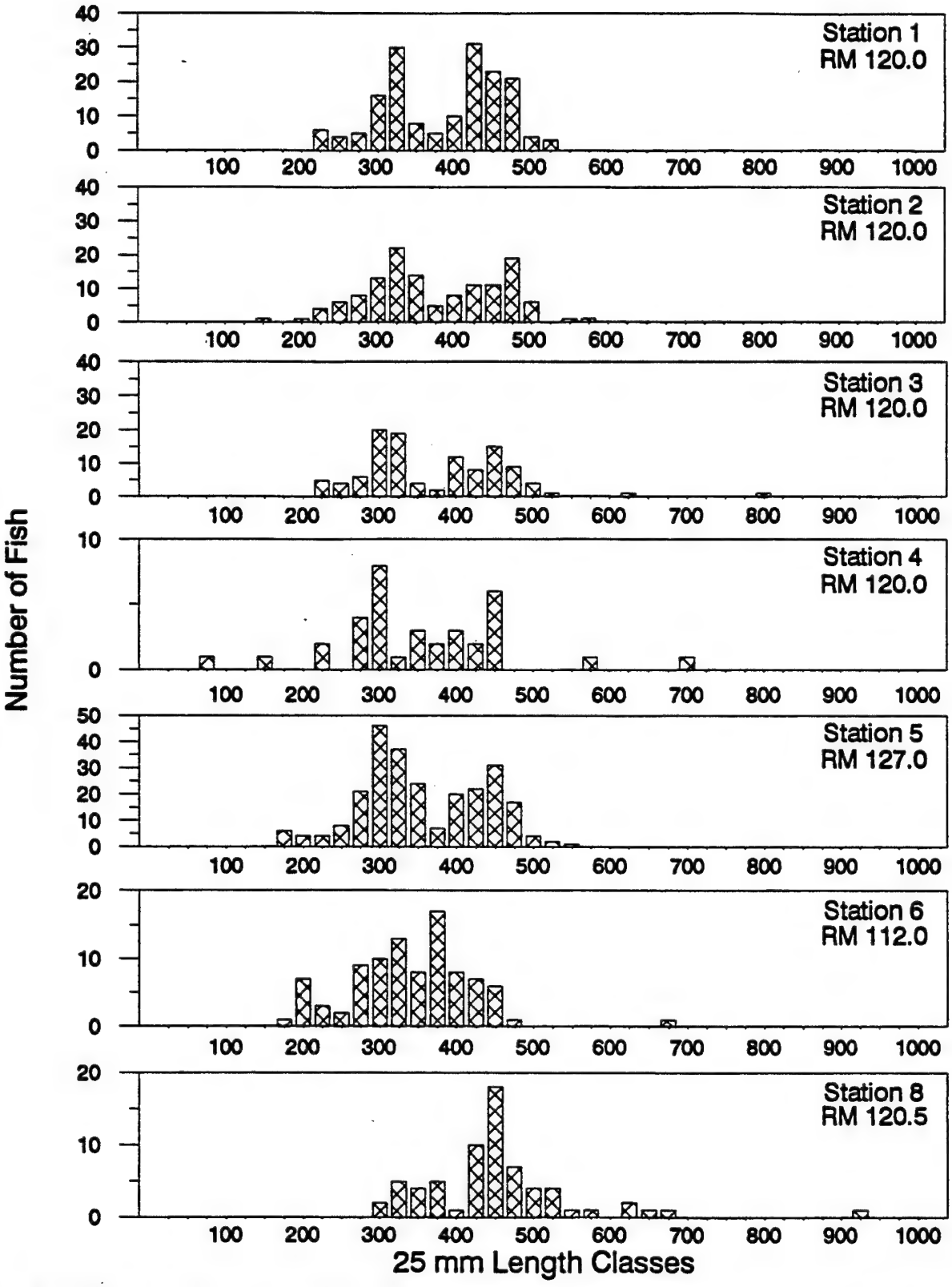
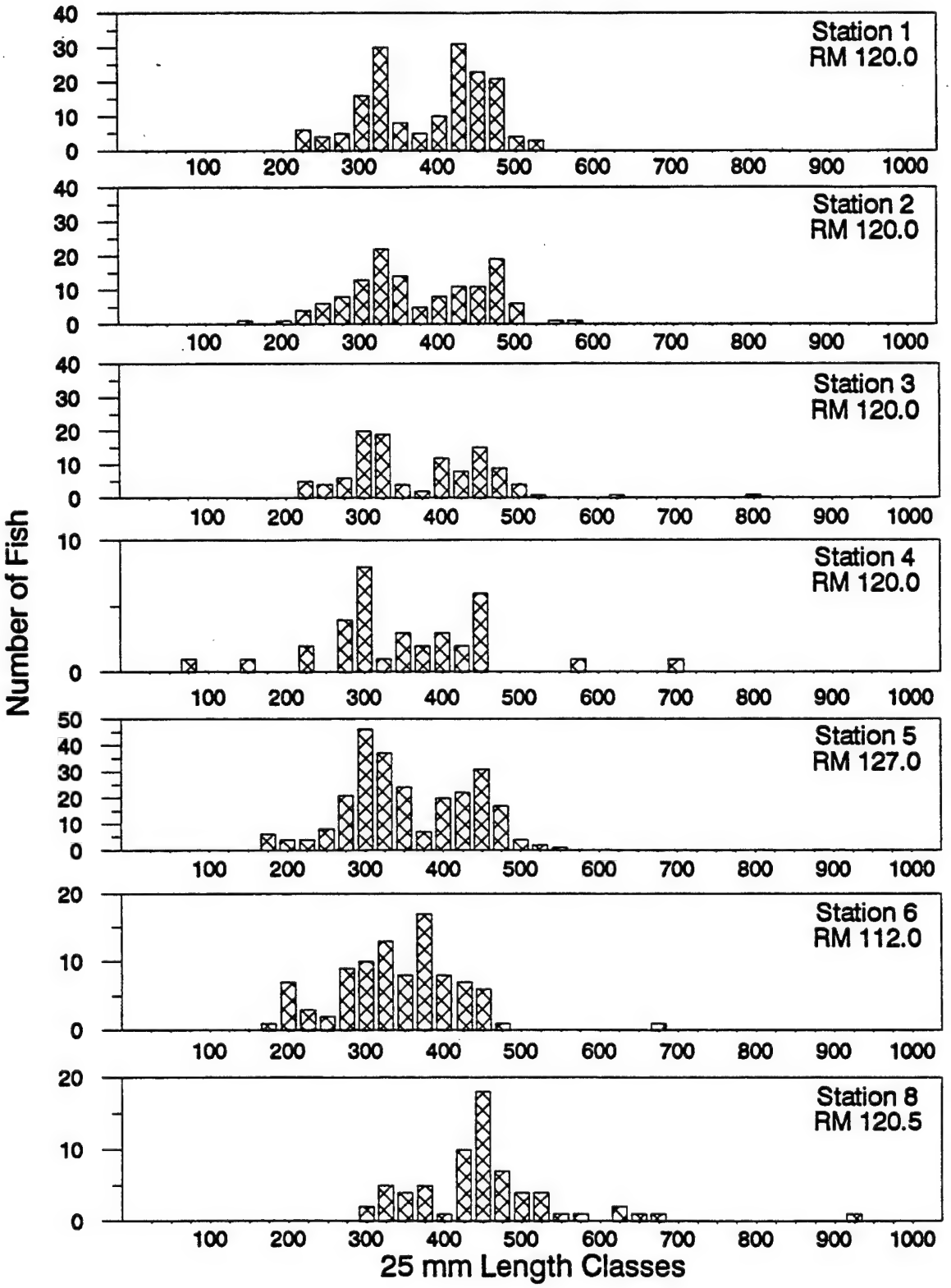
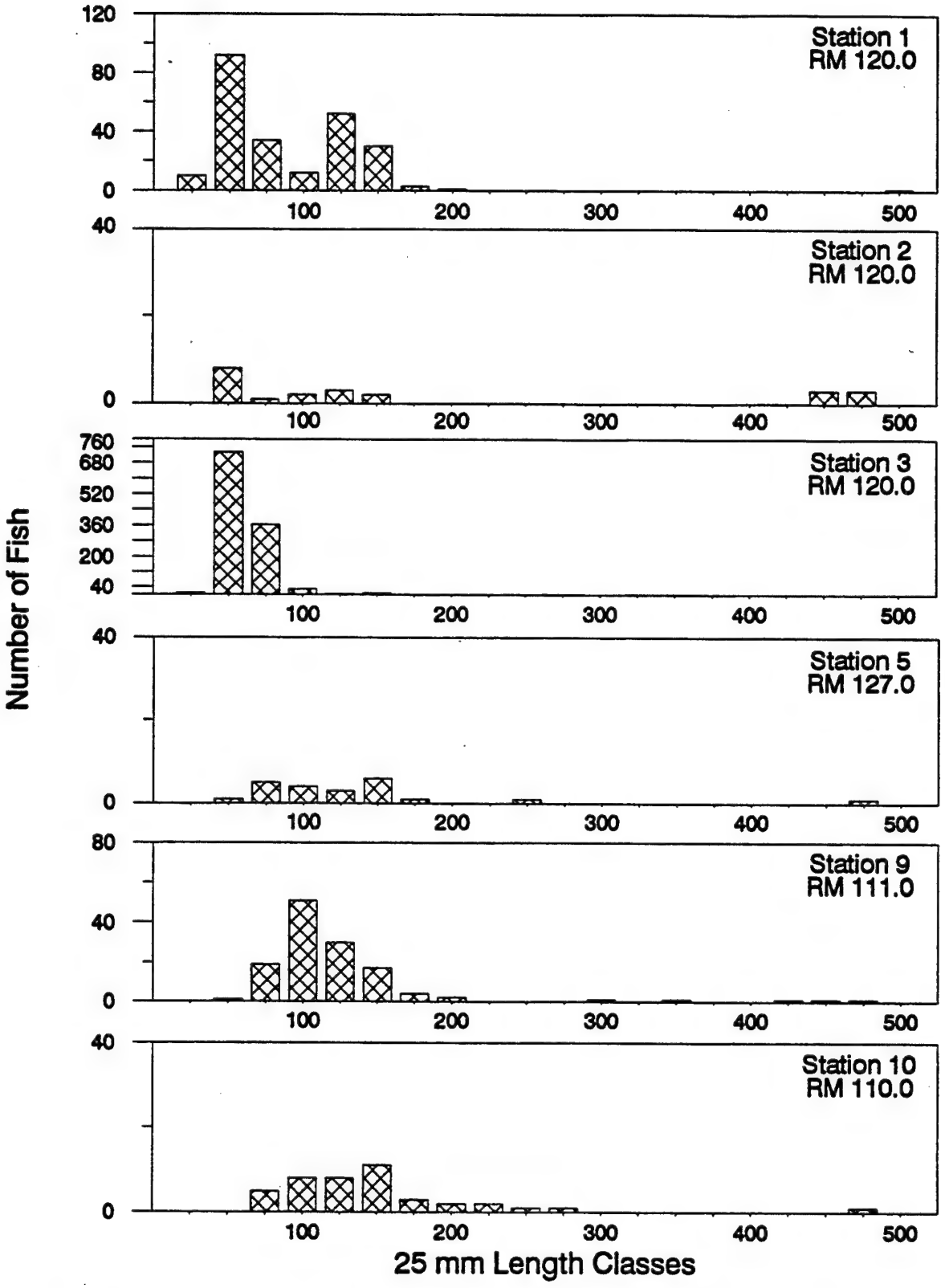


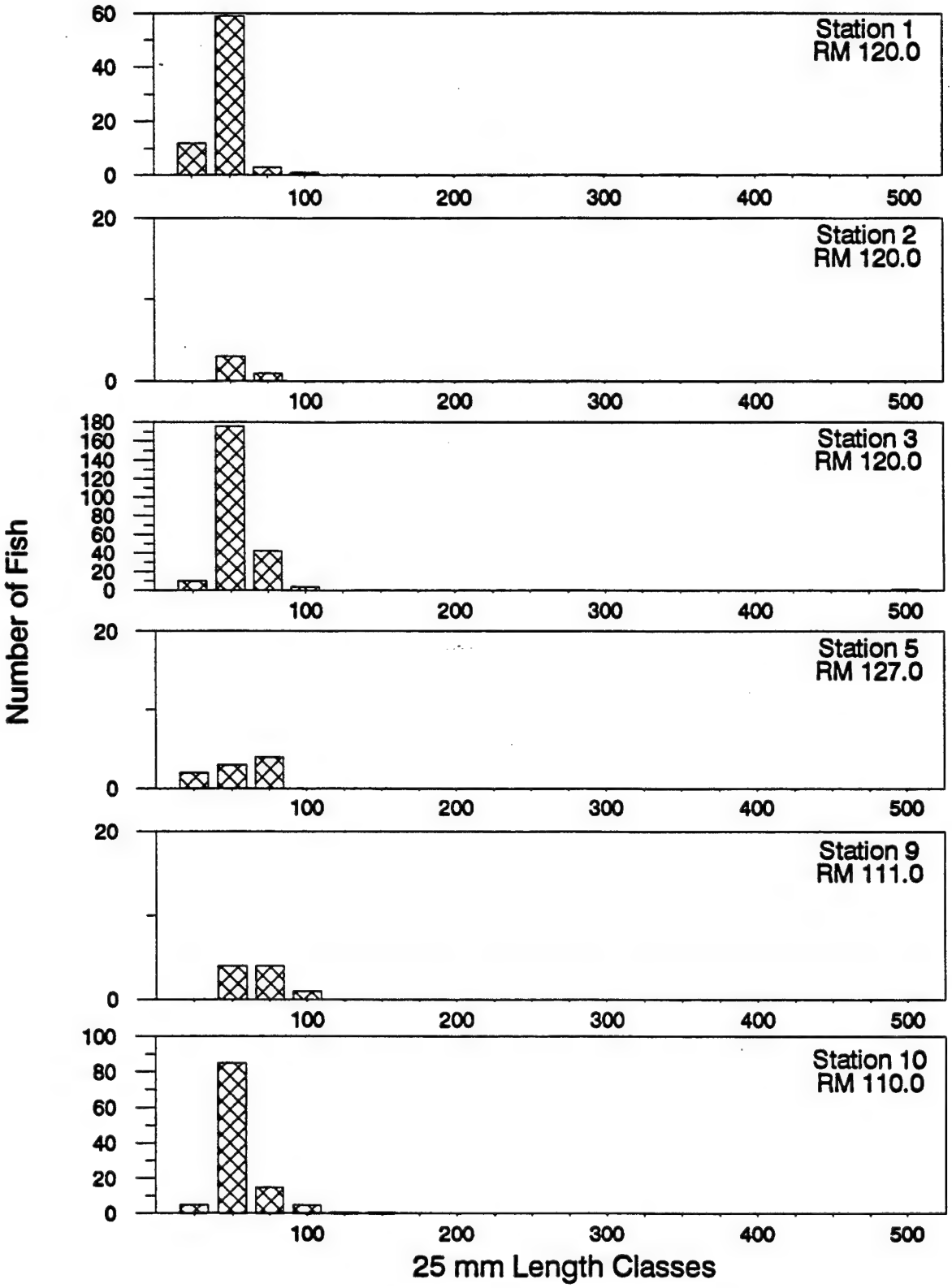
Appendix Figure 1. Length frequencies of fishes sampled by gill netting at disposal (1, 2 and 4) and reference (3, 5, 8, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during fall 1991.



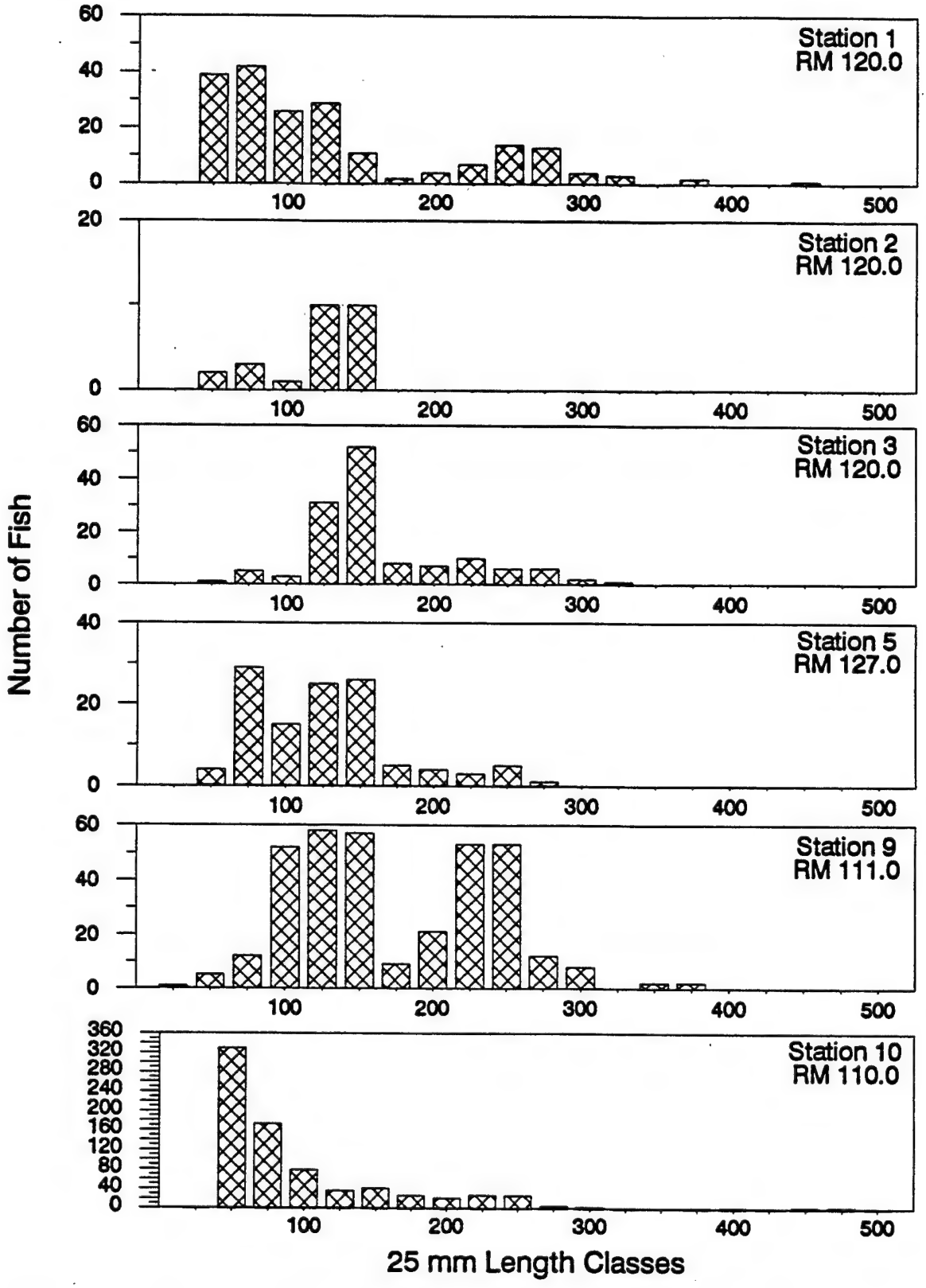
Appendix Figure 2. Length frequencies of fishes sampled by gill netting at disposal (1, 2 and 4) and reference (3, 5, 6, 8, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during spring 1991.



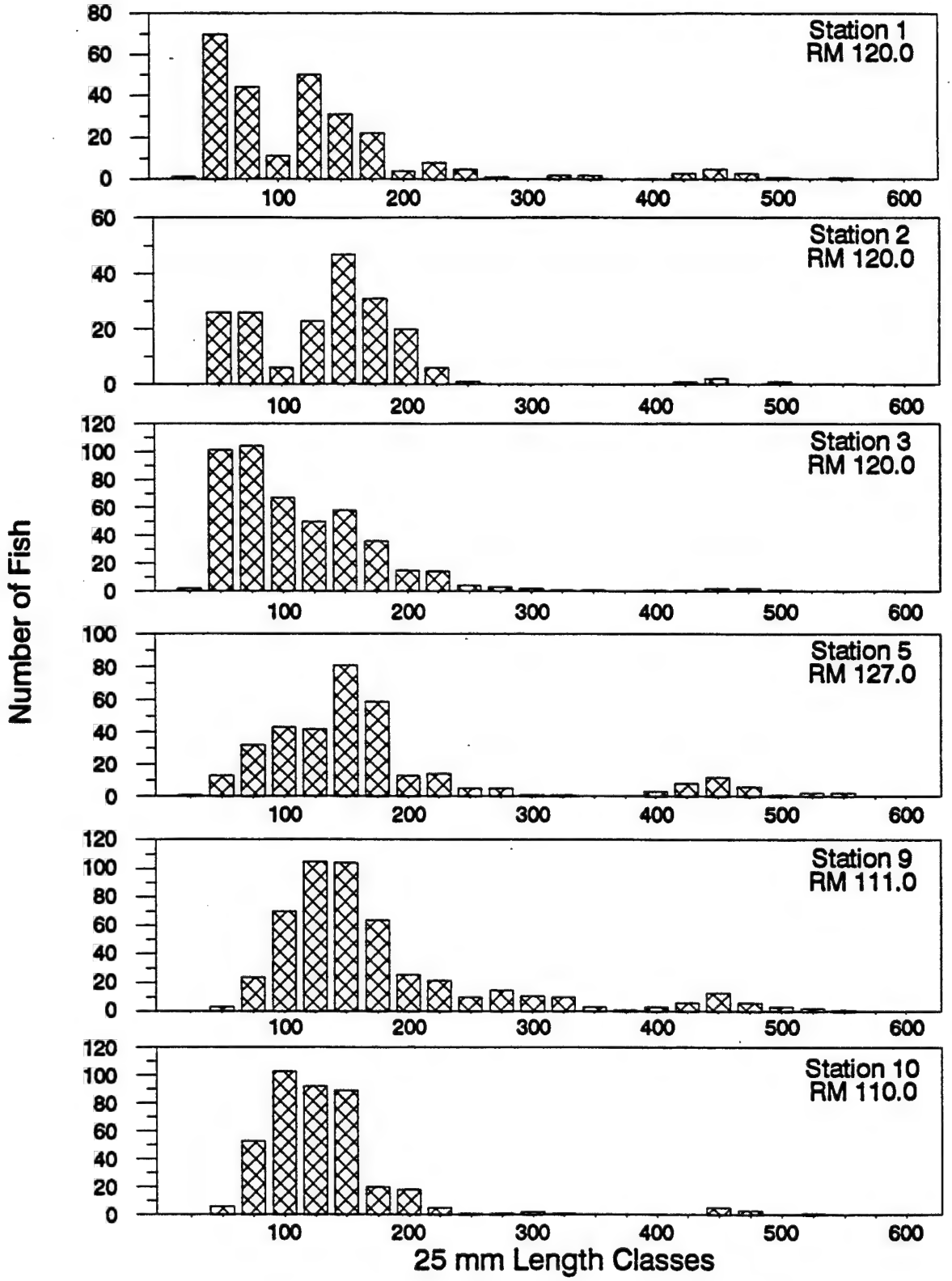
Appendix Figure 3. Length frequencies of fishes sampled by beach seining at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during 1991.



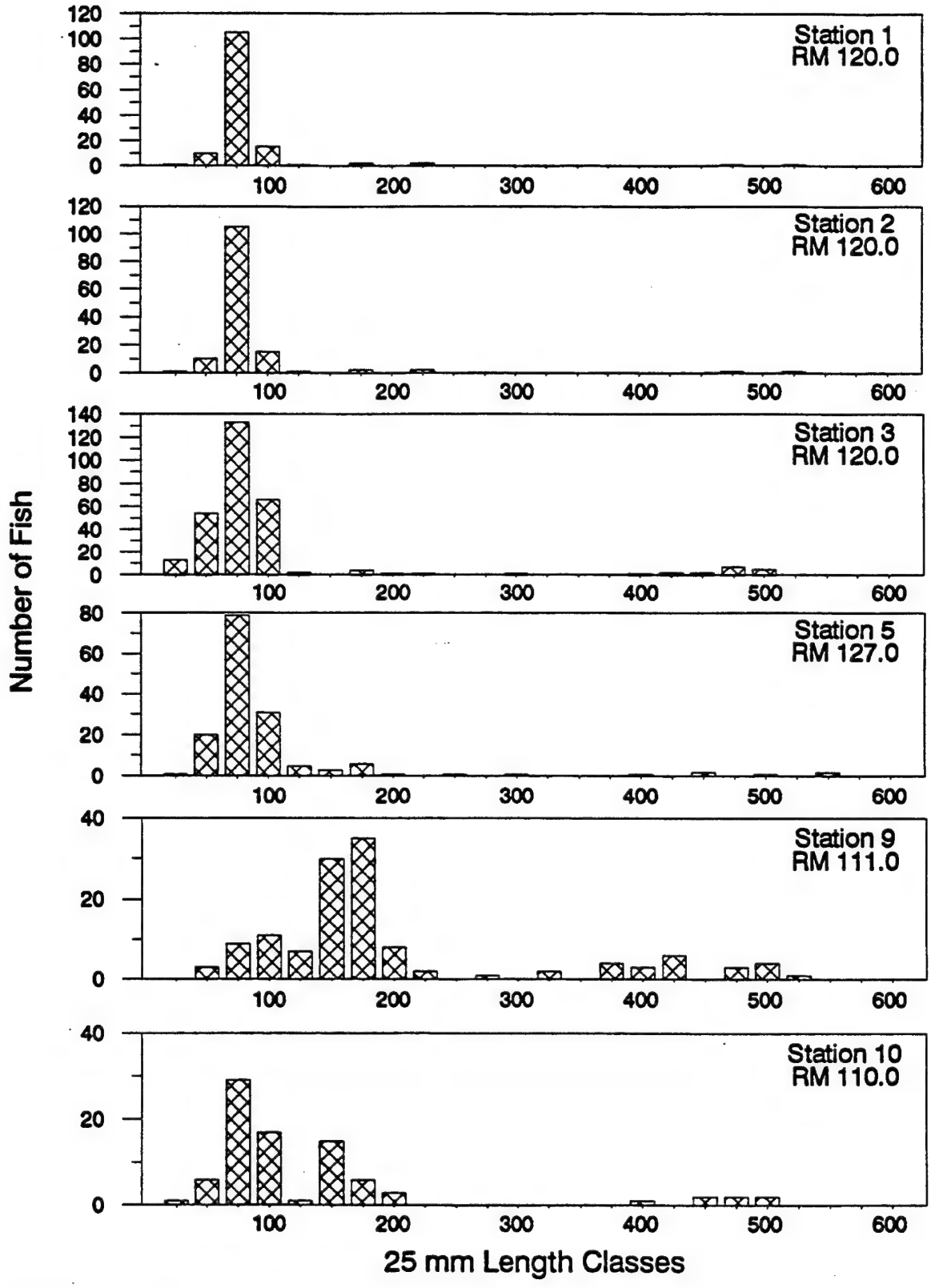
Appendix Figure 4. Length frequencies of fishes sampled by beach seining at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during fall 1991.



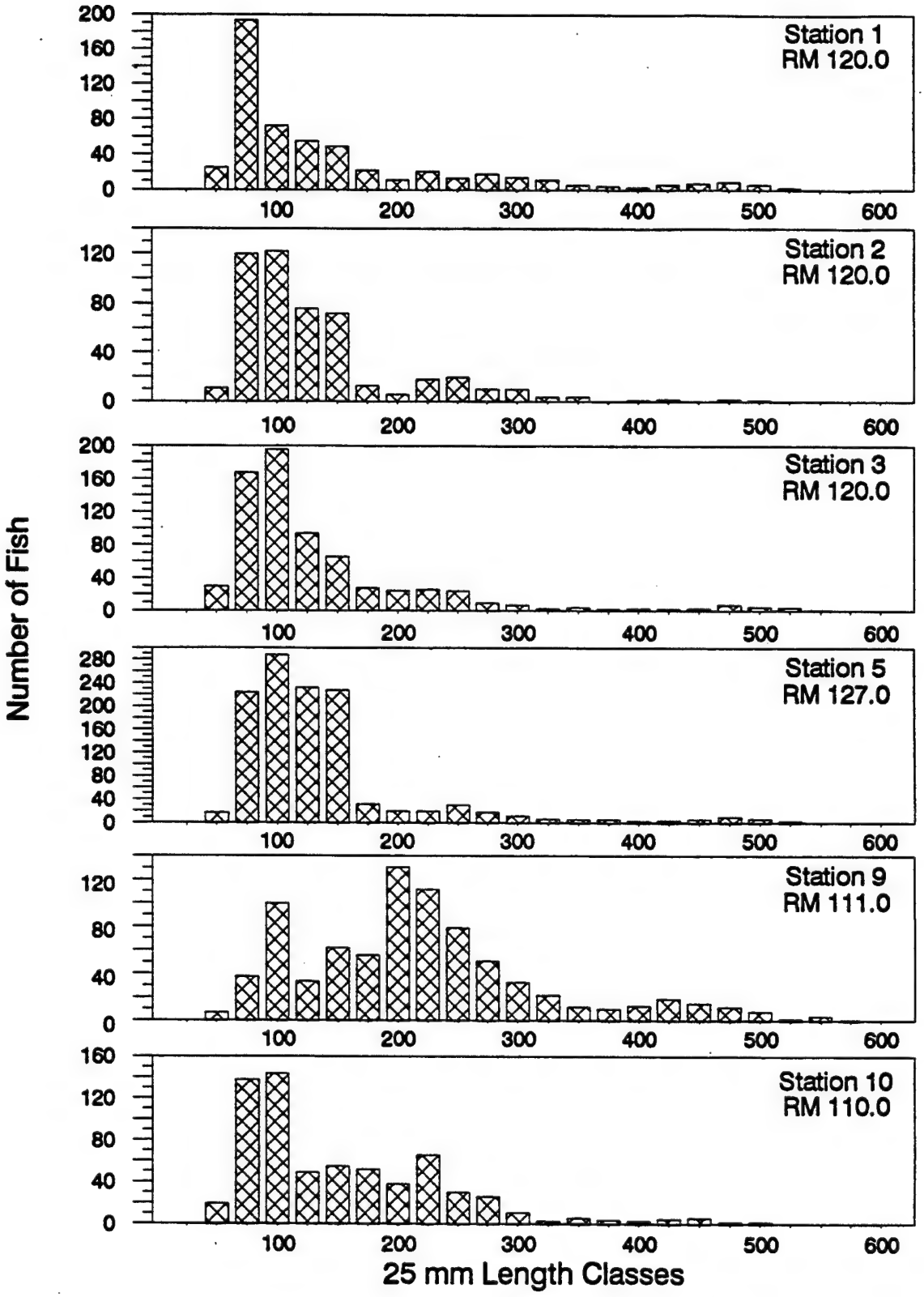
Appendix Figure 5. Length frequencies of fishes sampled by beach seining at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during spring 1991.



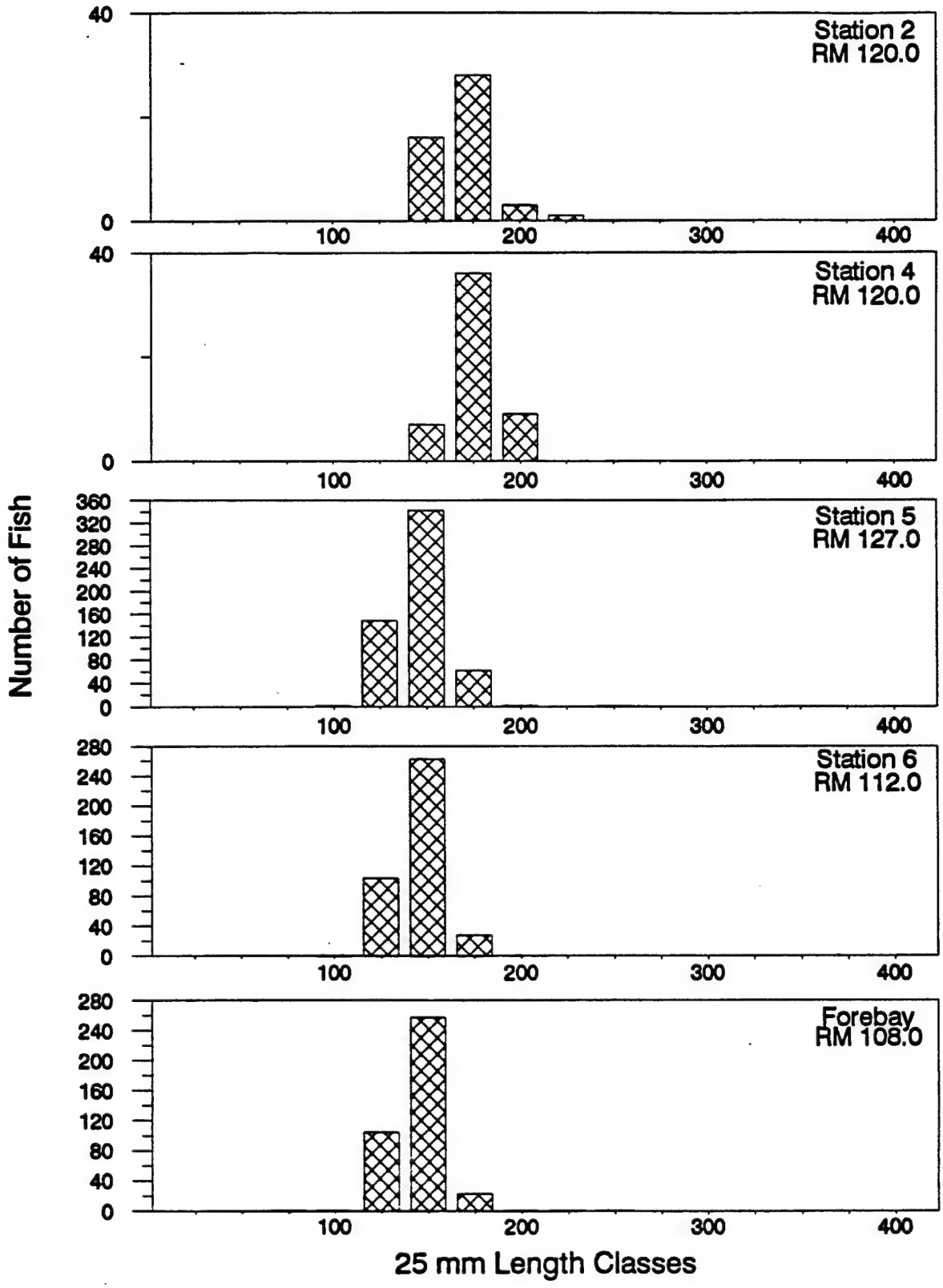
Appendix Figure 6. Length frequencies of fishes sampled by electrofishing at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during 1991.



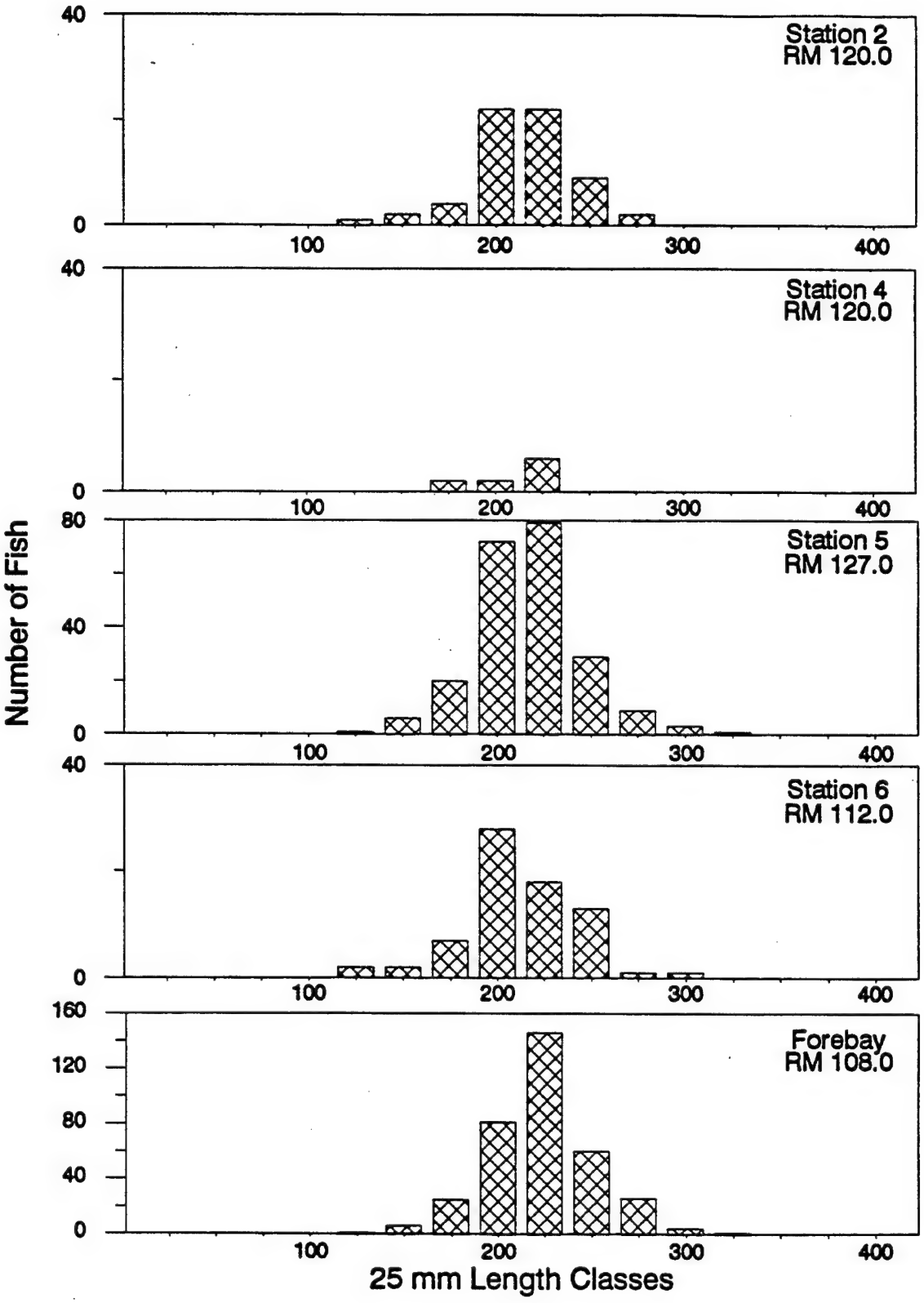
Appendix Figure 7. Length frequencies of fishes sampled by electrofishing at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during fall 1991.



Appendix Figure 8. Length frequencies of fishes sampled by electrofishing at disposal (1 and 2) and reference (3, 5, 9 and 10) stations in Lower Granite Reservoir, Idaho-Washington during spring 1991.



Appendix Figure 9. Length frequencies of juvenile chinook salmon sampled by surface trawling at disposal (2 and 4) and reference (5 and 6) stations and the forebay in Lower Granite Reservoir, Idaho-Washington during spring 1991.



Appendix Figure 10. Length frequencies of juvenile steelhead sampled by surface trawling at disposal (2 and 4) and reference (5 and 6) stations and the forebay in Lower Granite Reservoir, Idaho-Washington during spring 1991.

Appendix Table 1. Catch/volume of water filtered (No./10,000 m^3) for 1/2 m paired plankton nets in Lower Granite Reservoir during 1991. Upper and lower refer to bounds.

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PWI MEAN	PWI UPPER	PWI LOWER	TOTAL MEAN	TOTAL UPPER	TOTAL LOWER
21-JUN	1	180	1.5	0.196	53.014				20.95	97.46	0.00
	2	180	1.5	0.196	53.014	5.24	28.67	0.00	68.12	142.89	11.54
	4	180	1.5	0.196	53.014				62.88	156.61	0.00
	5	180	1.5	0.196	53.014				272.47	519.82	73.67
	11	180	1.5	0.196	53.014				178.16	420.02	18.40
29-JUN	1	180	1.5	0.196	53.014				157.19	263.13	70.42
	2	180	1.5	0.196	53.014				41.92	102.12	0.00
	4	180	1.5	0.196	53.014				99.55	317.35	0.00
	5	180	1.5	0.196	53.014				251.51	625.12	0.00
	11	180	1.5	0.196	53.014				413.94	1097.55	0.00
07-JUL	1	180	1.5	0.196	53.014				78.60	242.62	0.00
	2	180	1.5	0.196	53.014				73.36	238.39	0.00
	4	180	1.5	0.196	53.014				26.20	82.63	0.00
	5	180	1.5	0.196	53.014				403.45	1114.66	0.00
	11	180	1.5	0.196	53.014				1388.55	2622.08	334.48
12-JUL	1	180	1.5	0.196	53.014				73.44	119.37	0.00
	2	180	1.5	0.196	53.014				487.30	975.20	7.12
	4	180	1.5	0.196	53.014				52.40	138.82	0.00
	5	180	1.5	0.196	53.014				261.97	621.20	0.00
	11	180	1.5	0.196	53.014				2027.80	3776.55	292.97

Abbreviations: PWI-mountain whitefish, ASA-American shad, CYP-cyprinid, CCA-common carp, AAL-chiselmouth, POR-northern squawfish, MCA-peamouth, RBA-redside shiner, CSP-catostomid, CMA-largescale sucker, INE-brown bullhead, CEN-centrarchid, LSP-*Lepomis* spp., PSP-*Pomoxis* spp., MDO-smallmouth bass and PFL-yellow perch.

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PWI MEAN	PWI UPPER	PWI LOWER	TOTAL MEAN	TOTAL UPPER	TOTAL LOWER
16-JUL	1	180	1.5	0.196	53.014				146.72	414.77	0.00
	2	180	1.5	0.196	53.014				167.67	415.44	0.00
	4	180	1.5	0.196	53.014				104.80	228.79	0.00
	5	180	1.5	0.196	53.014				791.20	2083.23	0.00
	11	180	1.5	0.196	53.014				1650.52	3405.11	229.01
23-JUL	1	180	1.5	0.196	53.014				225.39	696.42	0.00
	2	180	1.5	0.196	53.014				450.62	1216.32	0.00
	4	180	1.5	0.196	53.014				487.32	998.26	67.31
	5	180	1.5	0.196	53.014				1194.67	2619.79	178.58
	11	180	1.5	0.196	53.014				2531.02	8782.30	0.00
29-JUL	1	180	1.5	0.196	53.014				561.57	1840.43	0.00
	2	180	1.5	0.196	53.014				661.37	2025.95	2.44
	4	180	1.5	0.196	53.014				842.47	1671.11	172.37
	5	180	1.5	0.196	53.014				2283.30	5100.22	73.03
	11	180	1.5	0.196	53.014				1472.34	3373.57	0.00
07-AUG	1	180	1.5	0.196	53.014				102.35	483.17	0.00
	2	180	1.5	0.196	53.014				62.87	280.95	0.00
	4	180	1.5	0.196	53.014				133.84	503.42	0.00
	5	180	1.5	0.196	53.014				461.11	1431.49	0.00
	11	180	1.5	0.196	53.014				565.88	1194.12	148.88
12-AUG	1	180	1.5	0.196	53.014				102.35	326.79	0.00
	2	180	1.5	0.196	53.014				141.71	600.13	0.00
	4	180	1.5	0.196	53.014				39.36	189.53	0.00
	5	180	1.5	0.196	53.014				220.45	778.42	0.00
	11	180	1.5	0.196	53.014				181.07	549.44	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	ASA MEAN	ASA UPPER	ASA LOWER	CYP MEAN	CYP UPPER	CYP LOWER
21-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
12-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				5.23	28.67	0.00
	11	180	1.5	0.196	53.014				52.40	52.40	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	ASA MEAN	ASA UPPER	ASA LOWER	CYP MEAN	CYP UPPER	CYP LOWER
16-JUL	1	180	1.5	0.196	53.014				110.04	258.61	0.00
	2	180	1.5	0.196	53.014				141.47	346.03	0.00
	4	180	1.5	0.196	53.014				104.80	228.79	0.00
	5	180	1.5	0.196	53.014				576.37	1570.33	0.00
	11	180	1.5	0.196	53.014	10.48	57.35	0.00	356.30	696.20	16.41
23-JUL	1	180	1.5	0.196	53.014				172.91	526.28	0.00
	2	180	1.5	0.196	53.014				298.67	599.67	0.00
	4	180	1.5	0.196	53.014				461.10	854.89	67.31
	5	180	1.5	0.196	53.014				953.64	1731.11	176.17
	11	180	1.5	0.196	53.014				1975.40	7269.22	0.00
29-JUL	1	180	1.5	0.196	53.014				259.83	890.69	0.00
	2	180	1.5	0.196	53.014				370.06	737.67	2.44
	4	180	1.5	0.196	53.014				574.77	977.16	172.37
	5	180	1.5	0.196	53.014				700.74	1328.46	73.03
	11	180	1.5	0.196	53.014				133.85	536.25	0.00
07-AUG	1	180	1.5	0.196	53.014	15.74	86.17	0.00	15.75	94.48	0.00
	2	180	1.5	0.196	53.014	10.48	28.67	0.00	5.24	28.67	0.00
	4	180	1.5	0.196	53.014	15.74	86.17	0.00	15.75	60.27	0.00
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014				5.24	28.67	0.00
12-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014				7.87	43.08	0.00
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				86.61	235.17	0.00
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CCA MEAN	CCA UPPER	CCA LOWER	AAL MEAN	AAL UPPER	AAL LOWER
21-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-JUL	1	180	1.5	0.196	53.014				5.24	28.67	0.00
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
12-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014				47.16	154.54	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CCA MEAN	CCA UPPER	CCA LOWER	AAL MEAN	AAL UPPER	AAL LOWER
16-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014				10.48	57.35	0.00
23-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014	36.68	112.97	0.00			
	11	180	1.5	0.196	53.014	104.80	288.71	0.00			
12-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	POR MEAN	POR UPPER	POR LOWER	MCA MEAN	MCA UPPER	MCA LOWER
21-JUN	1	180	1.5	0.196	53.014	10.48	40.12	0.00			
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014	20.96	67.83	0.00			
	5	180	1.5	0.196	53.014	20.96	90.47	0.00			
	11	180	1.5	0.196	53.014	94.32	252.55	0.00	5.24	28.67	0.00
29-JUN	1	180	1.5	0.196	53.014	10.48	40.12	0.00			
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014	5.23	28.67	0.00			
	5	180	1.5	0.196	53.014	15.72	47.16	0.00	26.20	143.36	0.00
	11	180	1.5	0.196	53.014	130.99	348.05	0.00			
07-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014	10.47	40.12	0.00	5.24	28.67	0.00
	11	180	1.5	0.196	53.014	78.60	251.75	0.00	26.20	118.16	0.00
12-JUL	1	180	1.5	0.196	53.014	41.92	111.43	0.00			
	2	180	1.5	0.196	53.014	10.48	40.12	0.00			
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014	41.92	120.34	0.00	10.48	40.12	0.00
	11	180	1.5	0.196	53.014	817.40	1461.71	173.10	309.15	624.40	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	POR MEAN	POR UPPER	POR LOWER	MCA MEAN	MCA UPPER	MCA LOWER
16-JUL	1	180	1.5	0.196	53.014				5.24	28.67	0.00
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014	151.95	404.55	0.00	68.11	293.12	0.00
23-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014	10.48	57.35	0.00			
	4	180	1.5	0.196	53.014	10.48	57.35	0.00			
	5	180	1.5	0.196	53.014	120.51	631.87	0.00			
	11	180	1.5	0.196	53.014	440.14	1228.83	0.00			
29-JUL	1	180	1.5	0.196	53.014	128.53	328.70	0.00			
	2	180	1.5	0.196	53.014	62.99	214.03	0.00			
	4	180	1.5	0.196	53.014	86.61	224.79	0.00			
	5	180	1.5	0.196	53.014	881.83	2036.00	0.00	204.71	604.33	0.00
	11	180	1.5	0.196	53.014	1307.00	2698.46	0.00	23.62	95.78	0.00
07-AUG	1	180	1.5	0.196	53.014				15.75	86.17	0.00
	2	180	1.5	0.196	53.014				10.48	57.35	0.00
	4	180	1.5	0.196	53.014	7.87	43.08	0.00	15.75	60.29	0.00
	5	180	1.5	0.196	53.014	73.36	221.56	0.00	73.36	252.55	0.00
	11	180	1.5	0.196	53.014	382.50	616.13	148.88	47.16	141.47	0.00
12-AUG	1	180	1.5	0.196	53.014	15.75	60.29	0.00			
	2	180	1.5	0.196	53.014	55.11	222.51	0.00	7.87	43.08	0.00
	4	180	1.5	0.196	53.014	7.87	43.08	0.00	7.87	43.08	0.00
	5	180	1.5	0.196	53.014	47.24			23.62	129.25	0.00
	11	180	1.5	0.196	53.014	141.72	359.92	0.00	7.87	43.08	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	RBA MEAN	RBA UPPER	RBA LOWER	CSP MEAN	CSP UPPER	CSP LOWER
21-JUN	1	180	1.5	0.196	53.014				5.24	28.67	0.00
	2	180	1.5	0.196	53.014				62.88	114.22	11.54
	4	180	1.5	0.196	53.014				41.92	88.78	0.00
	5	180	1.5	0.196	53.014				251.51	429.35	73.67
	11	180	1.5	0.196	53.014				78.60	138.80	18.40
29-JUN	1	180	1.5	0.196	53.014				146.71	223.01	70.42
	2	180	1.5	0.196	53.014				41.92	102.12	0.00
	4	180	1.5	0.196	53.014				94.32	288.68	0.00
	5	180	1.5	0.196	53.014				209.59	434.60	0.00
	11	180	1.5	0.196	53.014				282.95	713.50	0.00
07-JUL	1	180	1.5	0.196	53.014				68.12	185.28	0.00
	2	180	1.5	0.196	53.014				73.36	238.39	0.00
	4	180	1.5	0.196	53.014				26.20	82.63	0.00
	5	180	1.5	0.196	53.014				387.74	1045.87	0.00
	11	180	1.5	0.196	53.014	10.48	40.12	0.00	1273.27	2212.05	334.48
12-JUL	1	180	1.5	0.196	53.014				5.32	28.67	0.00
	2	180	1.5	0.196	53.014				476.82	946.53	7.12
	4	180	1.5	0.196	53.014				52.40	138.82	0.00
	5	180	1.5	0.196	53.014				199.11	403.40	0.00
	11	180	1.5	0.196	53.014	20.96	50.60	0.00	801.69	1483.50	119.87

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	RBA MEAN	RBA UPPER	RBA LOWER	CSP MEAN	CSP UPPER	CSP LOWER
16-JUL	1	180	1.5	0.196	53.014				31.44	127.49	0.00
	2	180	1.5	0.196	53.014				26.20	69.41	0.00
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				214.83	512.90	0.00
	11	180	1.5	0.196	53.014	10.48	40.12	0.00	1042.72	1856.42	229.01
23-JUL	1	180	1.5	0.196	53.014				5.32	28.67	0.00
	2	180	1.5	0.196	53.014				10.48	57.35	0.00
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				115.28	228.14	2.41
	11	180	1.5	0.196	53.014				115.48	284.25	0.00
29-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014				23.62	70.86	0.00
	4	180	1.5	0.196	53.014				7.87	43.08	0.00
	5	180	1.5	0.196	53.014				157.47	373.38	0.00
	11	180	1.5	0.196	53.014				401.55	812.48	0.00
07-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014				5.23	28.67	0.00
12-AUG	1	180	1.5	0.196	53.014				31.49	101.92	0.00
	2	180	1.5	0.196	53.014				23.62	129.25	0.00
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				7.87	43.08	0.00
	11	180	1.5	0.196	53.014	7.87	43.08	0.00			

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CMA MEAN	CMA UPPER	CMA LOWER	INE MEAN	INE UPPER	INE LOWER
21-JUN	1	180	1.5	0.196	53.014	5.23	28.67	0.00			
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
12-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CMA MEAN	CMA UPPER	CMA LOWER	INE MEAN	INE UPPER	INE LOWER
16-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
23-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014				20.95	80.24	0.00
	4	180	1.5	0.196	53.014				15.74	86.17	0.00
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014				20.95	90.47	0.00
12-AUG	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CEN MEAN	CEN UPPER	CEN LOWER	LSP MEAN	LSP UPPER	LSP LOWER
21-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014				5.24	28.67	0.00
	11	180	1.5	0.196	53.014						
12-JUN	1	180	1.5	0.196	53.014				5.24	28.67	0.00
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	CEN MEAN	CEN UPPER	CEN LOWER	LSP MEAN	LSP UPPER	LSP LOWER
16-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
23-JUL	1	180	1.5	0.196	53.014	47.16	141.47	0.00			
	2	180	1.5	0.196	53.014	130.99	501.95	0.00			
	4	180	1.5	0.196	53.014				15.72	86.02	0.00
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUL	1	180	1.5	0.196	53.014				86.61	293.73	0.00
	2	180	1.5	0.196	53.014				70.86	212.56	0.00
	4	180	1.5	0.196	53.014				23.62	95.78	0.00
	5	180	1.5	0.196	53.014				55.11	139.92	0.00
	11	180	1.5	0.196	53.014						
07-AUG	1	180	1.5	0.196	53.014				31.49	120.57	0.00
	2	180	1.5	0.196	53.014				15.72	86.02	0.00
	4	180	1.5	0.196	53.014				62.99	167.44	0.00
	5	180	1.5	0.196	53.014				78.60	227.17	0.00
	11	180	1.5	0.196	53.014						
12-AUG	1	180	1.5	0.196	53.014				15.75	60.29	0.00
	2	180	1.5	0.196	53.014				15.75	60.29	0.00
	4	180	1.5	0.196	53.014				7.87	43.08	0.00
	5	180	1.5	0.196	53.014				7.87	43.08	0.00
	11	180	1.5	0.196	53.014				7.87	43.08	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PSP MEAN	PSP UPPER	PSP LOWER	MDO MEAN	MDO UPPER	MDO LOWER
21-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUN	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
07-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
12-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PSP MEAN	PSP UPPER	PSP LOWER	MDO MEAN	MDO UPPER	MDO LOWER
16-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
23-JUL	1	180	1.5	0.196	53.014						
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014						
	11	180	1.5	0.196	53.014						
29-JUL	1	180	1.5	0.196	53.014	55.11	213.37	0.00	7.87	43.08	0.00
	2	180	1.5	0.196	53.014	31.49	172.34	0.00	118.10	646.27	0.00
	4	180	1.5	0.196	53.014				7.87	43.08	0.00
	5	180	1.5	0.196	53.014	31.49	135.95	0.00			
	11	180	1.5	0.196	53.014						
07-AUG	1	180	1.5	0.196	53.014	23.62	95.78	0.00			
	2	180	1.5	0.196	53.014						
	4	180	1.5	0.196	53.014						
	5	180	1.5	0.196	53.014	199.11	617.24	0.00			
	11	180	1.5	0.196	53.014						
12-AUG	1	180	1.5	0.196	53.014	39.36	104.29	0.00			
	2	180	1.5	0.196	53.014	31.49	101.92	0.00			
	4	180	1.5	0.196	53.014	15.75	60.29	0.00			
	5	180	1.5	0.196	53.014	39.37	140.20	0.00	7.87	43.08	0.00
	11	180	1.5	0.196	53.014				15.74	60.28	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PFL MEAN	PFL UPPER	PFL LOWER
21-JUN	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			
29-JUN	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			
07-JUL	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			
12-JUL	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014	5.23	28.67	0.00

Appendix Table 1 continued

DATE	STATION	DURATION Sec	SPEED M/Sec	AREA M2	VOLUME M3	PFL MEAN	PFL UPPER	PFL LOWER
16-JUL	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			
23-JUL	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014	5.24	28.67	0.00
	11	180	1.5	0.196	53.014			
29-JUL	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014	7.87	43.08	0.00
07-AUG	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			
12-AUG	1	180	1.5	0.196	53.014			
	2	180	1.5	0.196	53.014			
	4	180	1.5	0.196	53.014			
	5	180	1.5	0.196	53.014			
	11	180	1.5	0.196	53.014			

Appendix Table 2. Catch/volume of water filtered (No./10,000 m^3) for larval handbeam trawls in shallow (S; 0.5 m) and deep (D; 10 m) waters along the shoreline in Lower Granite Reservoir during 1991.

DATE	STATION	DEPTH	CYP MEAN	CYP BOUND UPPER	CYP BOUND LOWER	TOTAL MEAN	TOTAL BOUND UPPER	TOTAL BOUND LOWER
17-JUN	1	D				48.73	186.57	0.00
		S				0.00	0.00	0.00
	2	D				0.00	0.00	0.00
		S				0.00	0.00	0.00
	5	D				0.00	0.00	0.00
		S				97.46	373.14	0.00
	11	D				48.73	186.57	0.00
		S				194.93	470.61	0.00
29-JUN	1	D				16033.14	60968.82	0.00
		S				0.00	0.00	0.00
	2	D				0.00	0.00	0.00
		S				97.47	373.14	0.00
	5	D				0.00	0.00	0.00
		S				0.00	0.00	0.00
	11	D				24902.54	58403.08	9667.82
		S				35964.91	62971.23	0.00
07-JUL	1	D				161.12	1119.33	0.00
		S				1851.95	4404.55	0.00
	2	D				48.73	186.57	0.00
		S				97.47	373.14	0.00
	5	D				48.73	186.57	0.00
		S				97.47	373.14	0.00
	11	D				38499.02	68017.82	9522.37
		S	584.79	2238.85	0.00	74463.86	108255.01	10015.84
11-JUL	1	D				487.33	1865.70	0.00
		S				194.94	746.28	0.00
	2	D				0.00	0.00	0.00
		S				0.00	0.00	0.00
	5	D				0.00	0.00	0.00
		S				97.47	373.40	0.00
	11	D				2289.45	4691.12	0.00
		S				150098.22	1017129.41	1253.45

Abbreviations: CYP-cyprinid, AAL-chiselmouth, MCA-peamouth, POR-northern squawfish, RBA-redshide shiner, CSP-catostomid, CMA-largescale sucker, CEN-centrarchid, LSP-*Lepomis* spp., LGI-pumpkin seed, PSP-*Pomoxis* spp., MDO-smallmouth bass and PFL-yellow perch.

DATE	STATION	DEPTH	CYP MEAN	CYP BOUND UPPER	CYP BOUND LOWER	TOTAL MEAN	TOTAL BOUND UPPER	TOTAL BOUND LOWER
17-JUL	1	D				0.00	0.00	0.00
		S				97.47	373.14	0.00
	2	D				0.00	0.00	0.00
		S				682.26	2611.99	0.00
	5	D				0.00	0.00	0.00
		S	292.40	769.88	0.00	682.26	1986.77	0.00
	11	D	1364.52	3395.00	0.00	51276.05	86956.75	580.37
		S	779.72	2985.13	0.00	1584600.66	3157129.87	28656.90
24-JUL	1	D				2192.99	5328.47	0.00
		S				3996.11	8577.96	0.00
	2	D	48.73	186.57	0.00	1559.45	3743.82	0.00
		S	97.47	373.14	0.00	1314.94	2690.26	0.00
	5	D				0.00	0.00	0.00
		S				0.00	0.00	0.00
	11	D				1023.42	45452.28	0.00
		S				134600.43	506885.71	10212.04
30-JUL	1	D	243.66	932.85	0.00	2339.18	3788.17	0.00
		S	194.93	470.61	0.00	194.93	470.61	0.00
	2	D	292.40	705.91	0.00	389.87	1079.05	0.00
		S	584.80	1062.28	107.31	584.80	1062.28	107.31
	5	D	194.93	559.62	0.00	2193.00	6459.10	0.00
		S				1949.32	7462.82	0.00
	11	D	48.73	186.57	0.00	4873.30	15249.41	0.00
		S				58478.89	143839.35	0.00
07-AUG	1	D				3801.17	5980.41	2334.76
		S				243.66	932.85	0.00
	2	D				194.93	608.14	0.00
		S				292.40	1119.42	0.00
	5	D				2631.59	7540.32	0.00
		S				19883.04	75000.77	0.00
	11	D				1900.58	3172.60	887.44
		S				7212.49	16177.51	0.00

DATE	STATION	DEPTH	AAL MEAN	AAL BOUND UPPER	AAL BOUND LOWER	MCA MEAN	MCA BOUND UPPER	MCA BOUND LOWER
17-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
29-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D				3508.77	8082.41	0.00
		S						
07-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	1023.39	2588.93	0.00	2387.91	4317.64	458.19
		S	1267.06	4850.83	0.00	3898.64	4628.00	3169.27
11-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S				97.47	373.14	0.00
	11	D				633.53	1537.39	0.00
		S	3703.70	6153.96	1253.45	779.72	2587.45	0.00

Appendix Table 2 continued

DATE	STATION	DEPTH	AAL MEAN	AAL BOUND UPPER	AAL BOUND LOWER	MCA MEAN	MCA BOUND UPPER	MCA BOUND LOWER
17-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D				1665.92	2733.47	580.37
		S				5945.42	22761.60	0.00
24-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D				633.53	1537.39	0.00
		S	3703.70	6153.96	1253.45	779.73	2587.45	0.00
30-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D				1267.06	3842.08	0.00
		S	2046.78	7835.96	0.00	194.93	746.28	0.00
07-AUG	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	194.93	559.62	0.00	487.33	625.17	349.50
		S	1267.06	2645.43	0.00	584.80	2238.85	0.00

DATE	STATION	DEPTH	POR MEAN	POR BOUND UPPER	POR BOUND LOWER	RBA MEAN	RBA BOUND UPPER	RBA BOUND LOWER
17-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
29-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	3557.51	6405.78	709.23			
		S						
07-JUL	1	D						
		S	487.33	1481.29	0.00			
	2	D						
		S						
	5	D						
		S						
	11	D	8966.86	10324.40	7609.32			
		S	15497.08	27319.01	3675.14			
11-JUL	1	D						
		S	97.47	373.14	0.00			
	2	D						
		S						
	5	D						
		S						
	11	D	1267.06	2034.50	0.00			
		S	154970.80	500245.00	0.00			

DATE	STATION	DEPTH	POR MEAN	POR BOUND UPPER	POR BOUND LOWER	RBA MEAN	RBA BOUND UPPER	RBA BOUND LOWER
17-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S	97.47	373.14	0.00			
	11	D	31481.48	76063.15	0.00			
		S	27095.52	58480.14	0.00			
24-JUL	1	D						
		S	97.47	373.14	0.00			
	2	D						
		S						
	5	D						
		S						
	11	D	1267.06	2034.50	499.61			
		S	154970.80	500254.00	0.00			
30-JUL	1	D	97.47	373.14	0.00			
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	2485.38	8294.22	0.00			
		S	49415.20	110376.20	0.00			
07-AUG	1	D						
		S						
	2	D						
		S						
	5	D	146.20	559.71	0.00			
		S	1169.59	3357.69	0.00	97.47	373.14	0.00
	11	D	40448.34	66029.75	14866.94			
		S	169005.80	308192.00	29819.65			

DATE	STATION	DEPTH	CSP MEAN	BOUND UPPER	BOUND LOWER	CMA MEAN	BOUND UPPER	BOUND LOWER
17-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S	97.46	373.14	0.00			
	11	D	48.73	186.57	0.00			
		S	194.93	470.61	0.00			
29-JUN	1	D	15984.41	60782.25	0.00	D	D	D
		S						
	2	D						
		S	97.47	373.14	0.00	S	S	S
	5	D						
		S						
	11	D	17836.26	43914.89	0.00	S	S	S
		S	35964.91	62971.23	8958.59	S	S	S
07-JUL	1	D	146.1988	559.71	0.00	D	D	D
		S	1364.62	2823.26	0.00	S	S	S
	2	D	48.73	186.57	0.00	D	D	D
		S	97.47	373.14	0.00	S	S	S
	5	D	48.73	186.57	0.00	D	D	D
		S	97.47	373.14	0.00	S	S	S
	11	D	26120.86	50786.85	1454.86	D	D	D
		S	53216.37	71228.32	35204.43	S	S	S
11-JUL	1	D	341.13	1305.99	0.00	D	D	D
		S	97.47	373.14	0.00	S	S	S
	2	D						
		S						
	5	D						
		S	97.47	373.14	0.00	S	S	S
	11	D	389.86	1119.23	0.00	D	D	D
		S	130117.00	498143.30	0.00	S	S	S

DATE	STATION	DEPTH	CSP MEAN	BOUND UPPER	BOUND LOWER	CMA MEAN	BOUND UPPER	BOUND LOWER
17-JUL	1	D						
		S	97.47	373.14	0.00			
	2	D						
		S						
	5	D						
		S	97.46	373.14	0.00			
	11	D	16764.13	47659.13	0.00			
		S	1550780.00	3072903.00	28656.90			
24-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	389.89	43914.89	0.00			
		S	130117.00	498144.30	8958.59			
30-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D	1072.13	2926.54	0.00			
		S	6822.61	24880.91	0.00			
07-AUG	1	D						
		S	194.93	746.28	0.00			
	2	D	97.47	235.30	0.00			
		S						
	5	D	97.47	373.14	0.00			
		S	97.47	373.14	0.00	194.93	746.28	0.00
	11	D	1169.59	1801.24	537.94			
		S	5068.23	10173.80	0.00			

DATE	STATION	DEPTH	CEN MEAN	BOUND UPPER	BOUND LOWER	LSP MEAN	BOUND UPPER	BOUND LOWER
17-JUN	1	D				48.73	186.57	0.00
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
29-JUN	1	D				48.73	186.57	0.00
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
07-JUL	1	D				194.93	559.62	0.00
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
11-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						

DATE	STATION	DEPTH	CEN MEAN	CEN BOUND UPPER	CEN BOUND LOWER	LSP MEAN	LSP BOUND UPPER	LSP BOUND LOWER
17-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
24-JUL	1	D				1315.79	3210.74	0.00
		S				3898.64	8204.82	0.00
	2	D				292.40	292.40	0.00
		S				1120.86	2024.72	0.00
	5	D						
		S						
	11	D						
		S						
30-JUL	1	D				1120.86	3035.76	0.00
		S						
	2	D						
		S						
	5	D				1267.06	3485.34	0.00
		S				194.93	746.28	0.00
	11	D						
		S						
07-AUG	1	D				3411.31	4487.85	2334.76
		S						
	2	D				48.73	186.57	0.00
		S				292.40	1119.42	0.00
	5	D				1998.05	5113.91	0.00
		S	17251.46	66045.97	0.00			
	11	D						
		S						

DATE	STATION	DEPTH	LGI MEAN	BOUND UPPER	BOUND LOWER	PSP MEAN	BOUND UPPER	BOUND LOWER
17-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
29-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
07-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
11-JUL	1	D	146.20	559.71	0.00			
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						

DATE	STATION	DEPTH	LGI MEAN	BOUND UPPER	BOUND LOWER	PSP MEAN	BOUND UPPER	BOUND LOWER
17-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
24-JUL	1	D				779.73	1882.43	0.00
		S						
	2	D				974.66	2332.20	0.00
		S				97.47	373.14	0.00
	5	D						
		S						
	11	D						
		S						
30-JUL	1	D				925.93	2364.99	0.00
		S						
	2	D						
		S						
	5	D				487.33	1481.29	0.00
		S						
	11	D						
		S						
07-AUG	1	D				341.13	1305.99	0.00
		S						
	2	D				48.73	186.57	0.00
		S						
	5	D				97.47	373.14	0.00
		S				877.19	3358.27	0.00
	11	D						
		S						

DATE	STATION	DEPTH	MDO MEAN	BOUND UPPER	BOUND LOWER	PFL MEAN	BOUND UPPER	BOUND LOWER
17-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
29-JUN	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
07-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						
11-JUL	1	D						
		S						
	2	D						
		S						
	5	D						
		S						
	11	D						
		S						

DATE	STATION	DEPTH	MDO MEAN	BOUND UPPER	BOUND LOWER	PFL MEAN	BOUND UPPER	BOUND LOWER
17-JUL	1	D						
		S						
	2	D						
		S	682.26	2611.99	0.00			
	5	D						
		S	194.93	746.28	0.00			
	11	D						
		S						
24-JUL	1	D	97.47	235.30	0.00			
		S						
	2	D	243.66	932.85	0.00			
		S	97.47	292.40	0.00			
	5	D						
		S						
	11	D						
		S						
30-JUL	1	D	48.73	186.57	0.00			
		S						
	2	D	97.47	373.14	0.00			
		S						
	5	D	243.66	932.85	0.00			
		S	1754.39	6716.54	0.00			
	11	D						
		S						
07-AUG	1	D				48.73	186.57	0.00
		S	48.73	186.57	0.00			
	2	D						
		S						
	5	D	292.40	1119.42	0.00			
		S	194.93	746.28	0.00			
	11	D	48.73	186.57	0.00			
		S	292.40	1119.43	0.00			